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THE DEPTHS OF THE EARTH[1]

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INTRODUCTION

CHARLES LAPWORTH was one of the intellectual princes of our profession. He it was who discovered the "Secret of the Highlands." In another Scotland Yard he triumphantly illustrated the British genius for detective work. His penetrating eye saw in principle, and later Peach and Horne proved, the majesty of the Scottish thrusts. Thus a revolutionary idea became generally accepted. Yet a still more vital secret underlies the secret explained by the brilliant Lapworth. That further mystery, still unsolved to general satisfaction, is the cause of the clean-cut slicing and plastic shearing of the rocks when mountains are made. Clearly the data for solving the mystery must be sought under all the lands and seas—in the earth's vast interior.

There, too, is the condition for the isostatic rise of the crust when the regional ice-caps melted, or when continents lost weight by denudation and rose to renew their equilibrium. There ultimately is the key to the problem of former land bridges between continents and the key to paleogeographic problems in general. The petrologist also can not escape the necessity of thinking intensely about the third dimension, depth, as well as about the two dimensions of the maps. In short the geologist, however specialized, has to be a courageous soul and venture where angels can not tread. The equipped geologist shall know not only his six continents and the seven seas; he shall faithfully treasure every scrap of information that may come to him regarding the invisible and intangible, where lies the secret of secrets of all geological science.

[1] Presidential address read before the Geological Society of America, December 28, 1932. Somewhat abridged; illustrations and references omitted; to be printed in full in the *Bulletin* of the Geological Society.

To go down in imagination is an adventure, daring but thoroughly essential, for in depth is the seat of dominating energy and the origin of all rocks whatever.

Since the year 1900 discoveries and fertile hypotheses about conditions beneath the accessible part of our planet have been pouring into the literature and summarized in thick handbooks. The young science, geophysics, has become a giant with a giant's power to move, and then in a measure to fix, the foundations of geological thought. This evening I offer a speculative and of course tentative picture of the earth's interior in the light of the new geophysics, checked by facts of geology and by the possibilities of cosmogony.

The Shells and Core of the Earth

In principle the picture is given in Tables I and II. The first shows the kinds, states and densities of the materials constituting a typical continental sector.

TABLE I

Earth-Shells in Continental Sector

(Crystalline Archean rocks at surface)

Depth (km)	Material, with average density	
0–30	Granite and piezo-granite	SIAL (2.8)
	Discontinuity	
30–40	Granodiorite and piezo-phases	SIAL (2.8)
	Discontinuity	
40–60	Piezo-gabbro.....CRYSTALLIZED SIMA (3.05)	
	Discontinuity	
60–100±	Vitreous basalt (2.8–2.9)	
100±–1200	Vitreous ultrabasic silicate (2.9–4.5)	
	Discontinuity	
1200–2900	Vitreous silicate + oxide + sulphide (5.0–6.5)	
	Discontinuity	
2900–6370	Central core of iron (liquid?; 10.5–12.5)	

TABLE II

Earth-Shells in Sector under Deep, Open Pacific

Depth (km)	Material, with average density
0–5.2	Water (1.03)
	Discontinuity
5.2–74.8±	Basalt and piezo-gabbro (CRYSTALLIZED SIMA; 2.95–3.05)
	Discontinuity
74.8±–100±	Vitreous, femic basalt (2.85–2.9)
Below 100	Shells as in Table I

Table II similarly refers to the broad sector underlying the deeper part of the open Pacific Ocean. Somewhat different from either, at levels above the depth of 80 kilometers, would be any of the sectors capped by lofty chains of mountains or by oceans shallower than the deep Pacific.

This sketch of the earth's anatomy is based upon:

(1) The seismologists' determinations of wave velocities and changes of velocity in depth, with corresponding discontinuities of the material;

(2) The known composition of the upper part of the Sial;

(3) The dominantly basaltic quality of lava floods;

(4) The world-wide distribution of basaltic eruptives and the genetic association of basaltic magma with other observed igneous magmas and rocks (eruptive sequence);

(5) The necessity of assuming a distribution of densities to match the earth's moment of inertia and its mean density;

(6) The commonly accepted postulate that the earth's core is composed essentially of metallic iron, which, according to some high authorities, acts like a liquid against the weak, rapidly alternating stresses of earthquake waves;

(7) Experimental and seismological evidence as to the compressibilities of rock matter and iron, and the relation of the compressibilities to the speeds of earthquake waves;

(8) The observed and calculated thermal gradients in the planet;

(9) The probable distribution of radioactivity;

(10) The systematic differences of thermal conductivity among rocks, whether crystalline or vitreous;

(11) The probable origin of the earth;

(12) The composition of meteorites;

(13) The extreme weakness of the material below the depth of a few scores of kilometers (permitting isostatic adjustment);

(14) The facts bearing on orogenesis.

An Earth Largely Vitreous

Here again are fourteen points. Not all of them make universal appeal and no treaty of Versailles is likely to bring peace soon in this other war of opinion. Full discussion of any of the points is out of the question, and whole fields of inquiry bearing on the nature of the earth's interior must be left untouched. Our time will be occupied chiefly with one fundamental assumption—that all but a small fraction of the 2,900-kilometer envelope of the planet's core is in the vitreous state. This implies the reality of a true crust, in the sense of a thin crystallized shell resting upon a series of non-crystallized shells; earth temperatures to correspond; strength nearly, if not quite, confined to the crust; and, because of the relations of density, potential instability for limited belts of the crust. The validity of this general idea is one

of the most pressing and significant problems of earth science.

Cosmogony and the Vitreous Shells: First we observe that all the modern views about the earth's origin permit the hypothesis described. The erupto-tidal theory of Chamberlin and Moulton, the gas-filament tidal theory of Jeans and Jeffreys, the collision theory of Bickerton and Jeffreys, and the capture-collision theory of Hirayama and Van Anda all start with a gaseous earth. Chamberlin and Moulton argued for the rapid solidification of the young earth and for a tremendous increase of mass by the infall of planetesimals, the earth remaining crystalline except for subordinate, liquid pockets of quasi-eutectic composition. Yet it appears that these authors exaggerated the rôle of planetesimals in the earth's organization. Moreover, in any case the solar belch responsible for our globe may, by the erupto-tidal theory, have been big enough to retain the gaseous condition until the earth had attained practically its present mass. Jeffreys dates the segregation of the iron core at the gaseous stage—its most plausible explanation. He assumes that, after liquefying, the thick envelope about the core was "probably" made homogeneous in a chemical sense by thermal convection, and then by continued stirring was rapidly cooled and crystallized at great depth. However, it seems logical to think that the envelope itself was originally stratified, the intrinsic (chemically determined) density increasing with depth. If so, early thermal or other types of convection would cool only the outer part of the envelope about the core. Thus the initially high temperatures and non-crystalline character of all shells below the depth of a few hundreds of kilometers would be long preserved. Like the others, then, Jeffreys' cosmogonic scheme does not forbid belief that below a crust of moderate thickness the shells of the envelope are still too hot to pass out of the vitreous state.

Seismology and the Earth-shells: By general agreement the upper part of the Basement Complex (Archean terrane) is regarded as chiefly granitic. According to Sederholm's careful measurements in a regional sample (Finland), its average composition lies between those of average granite and average granodiorite. At depths greater than a few kilometers the Sial should be somewhat more basic because of an increased proportion of femic injections, and the lower half of the Sial may, in average, approximate granodiorite. There the density is doubtless increased still further by load metamorphism. Although these deeper rocks of the Sial are probably gneissic, their exact nature remains obscure. Hence there is some advantage in giving them the non-committal names of "piezo-granite" and "piezo-granodiorite."

Similarly, between the 40-kilometer and 60-kilometer levels the crystallized Sima, chiefly basaltic in chemical composition, is not likely to be gabbro or diabase, but denser rock. Its phases may be grouped under the name "piezo-gabbro."[2] The velocities of the earthquake waves are explicable if the Sial and crystallized Sima have the constitution described.

That the material just below the 60-kilometer discontinuity is vitreous basalt is an assumption at least permitted by studies of compressibility. Bridgman's pressure-volume curve for tachylite at 75° is relevant. It gives a rather close approximation to the compressibility of basaltic glass at pressures corresponding to depths of 60, 70 and 80 kilometers below the earth's surface. The density of the glass under these conditions is known within narrow limits. Taking the accepted value of Poisson's ratio at 0.27, the closely approximate velocity (V_P) of the longitudinal wave in tachylite at 75° and at the depths stated is found. Table III (col. 4) shows the result of such computation as well as the densities and elastic data. The expected high temperature of the glass at these levels is not allowed for in the calculation of wave velocity. Heating tends slightly to reduce compressibility and therefore wave velocity, but the correction required for this reason may be more than offset by proper correction for the difference between the high-pressure or static modulus of elasticity and the somewhat higher, seismically-effective or dynamic modulus for the same rock. Now the actual velocities of the longitudinal wave at the depths of 60, 70 and 80 kilometers within the earth have, according to the seismologists, the values shown in the last column of Table III. Comparison of this and the preceding column shows how well vitreous basalt meets the needs of the case. The agreement would be much poorer if crystalline peridotite were assumed at these depths, and is probably better than if vitreous peridotite be assumed.

TABLE III

DATA REGARDING A TACHYLITIC EARTH-SHELL

Depth (km)	Volume compressibility	Density	Computed V_P (km/sec)	"Observed" V_P (km/sec)
60	1.13×10^{-6}	2.80	7.4	7.8
70	1.07×10^{-6}	2.82	7.6	7.9
80	1.00×10^{-6}	2.85	7.8	8.0

[2] No important phase of this layer seems to be as dense and incompressible as eclogite.

Gutenberg's depth-velocity curve suggests only moderate chemical change between the 100-kilometer level and the discontinuity at 1,200 kilometers. Vitreous peridotite, perhaps merging into material like the average stony meteorite, would give the corresponding densities and wave velocities of Tables I and II, at these greater depths.

The meaning of each of the discontinuities, tentatively located by Gutenberg at 1,200, 1,700 and 2,450 kilometers of depth, is an unsolved problem. Goldschmidt supposes the changes of material to be in the direction from dominant silicate to dominant sulphide or oxide. The "observed" wave velocities seem to permit, though they do not compel, the idea of a vitreous condition for what Gutenberg calls the "intermediate layer," that between the 1,200-kilometer and 2,900-kilometer levels.

In conclusion, seismology has given results not unfavorable to our main thesis—non-crystallinity for all earth-shells below the thin crust. Experiments like those of Bridgman on liquids suggest that pressure alone can give the "glass" effective "solidity" in its reaction to the weak, short-lived stresses of earthquake waves. That the temperatures are high enough to prevent crystallization is a premise which would be strengthened if, as Oldham, Knott, Visser, Jeffreys and Gutenberg think, the earth's core acts as a true liquid against the stresses of earthquake waves; for presumably the temperature of the core would have to be exceedingly high to counteract the "solidifying" effect of the one to three millions of atmospheres of pressure upon the core material.

Evidence from Thermal Gradients: A review of the best data gives 1° C. per 36 meters or 28° per kilometer of depth as a good average gradient of temperature at the surface of the Archean complex. Extrapolation to depth is famously difficult. On any reasonable set of assumptions the gradient must, with increasing depth, become less steep: slowly near the surface and then faster to some moderate depth, where the rate of change becomes lower again. The troubles in calculating the gradients at depths greater than about 25 kilometers are numerous and of differing importance. There are two major troubles. One is connected with uncertainty regarding the distribution of radioactivity in the rocks; the other with uncertainty regarding the content of primitive, non-radioactive heat in those earth-shells which, through geological time, have actually felt the cold of outer space. Minor difficulties relate to the proper values to be assigned to the age of the earth and to the conductivity and specific heat of each of the outer earth-shells.

Because the crust has existed continuously since the Early Archean, all authorities assume strong concentration of radioactivity in the superficial shells. Jeffreys and others believe that the thermal output of the radioactive furnace is less than the heat lost by radiation from the surface, a large fraction of this squandered energy being an original endowment of the planet. Joly and Holmes, though also assuming much concentration of radioactivity in the crust, find the radioactive furnace efficient enough to endanger the continued existence of the crust, if unmoved.

According to Joly's well-known theory the crust persists, because periodically thinned by melting and then dragged over the earth's body; for both reasons the excess heat is supposed to have been rapidly conducted and radiated away. To this theory there are physical and geological objections, apparently fatal.

Holmes appeals to continental migration as the leading cause for the dissipation of the excess heat. The migration is thought to have been compelled by periodic convection and overturn of the whole 2,900-kilometer envelope about the earth's core. This bold suggestion implies that compression alone accounts for the downward increase of density in the envelope. Yet, as Williamson and Adams showed, mere compression of either basalt or peridotite could not give densities matching the earth's moment of inertia and mean density. There are other formidable objections to Holmes's theory, but here too time fails for their discussion.

Considering all the facts of the case, I think it most probable that no more than half of the heat radiated from the globe is of radioactive origin, the rest being original heat.

Holmes in 1915 and later Adams and then Jeffreys computed the temperatures to depths of 100 or more kilometers, on two assumptions: moderate heat of radioactivity, and little or no secular loss of heat from depths greater than a few hundreds of kilometers. Holmes deduced temperatures of 600°, 1204° and 1575° at the respective depths of 20, 60 and 100 kilometers. Both Adams and Jeffreys found considerably lower temperatures for the same depths.

All three sets of calculations are affected by the uncertainty as to the law of diminution of radioactivity with increasing depth, and all three ignore the possibility of thermal convection in the earth's body. The latter process would seriously affect the quantity of original heat to be dissipated in the course of time. While the single-step convection through the 2,900-kilometer envelope can not be assumed, Holmes has recently done good service in once more emphasizing (with Jeffreys) the possibility of convective transfer of primitive heat. If hot enough to be vitreous, the earth-shells at depth may reasonably be considered as infinitely weak (liquevitreous), whatever rigidity they exhibit against seismic and tidal stresses. In

any of these shells convection is possible, provided: (1) the thermal gradient is steep enough; (2) the intrinsic (chemically determined) density is not far from uniform; (3) the shell is at least a few hundreds of kilometers thick; and (4) the viscosity is not many times higher than that of steel. Surface cooling establishes a thermal gradient in the topmost liquevitreous layer. Suppose this layer to be convectively overturned. The next shell beneath is chilled and thus has its own gradient steepened. Suppose it also to be convectively overturned. A third layer is then liable to the same change; and so on. These changes take much time, but it is conceivable that at long intervals original heat is brought from great depth to the base of the earth's crust. This speculative process, involving a slow, downward transfer of cold from shell to shell, may be briefly described as *delayed, tandem convection.* If such a mechanism has been at work, it is obviously wrong to postulate a fixed "initial" temperature for the outer earth, a temperature controlled wholly or essentially by the relation of melting temperature to pressure. For this reason the gradients calculated by Holmes, Adams and Jeffreys may be less steep than the true gradient.

Their assumptions of minor importance should also be examined. In each of the three calculations the thermal conductivity of crust rocks is taken at too high a value. Not enough allowance is made for the decrease of conductivity with increase of temperature; nor for the fact that the statically metamorphosed rocks of the crust, with the expected flat-lying schistosity, conduct heat in a vertical direction more slowly than the chemically equivalent but unlayered rocks (granite to gabbro) conduct heat. Moreover, Holmes (since 1929) and Jeffreys assume a vitreous state for earth-shells well within the layer affected by secular cooling, and should in their computations have allowed for the conductivity of vitreous rock, which, at ordinary temperature at least, is much lower than that of the equivalent crystalline rock. Again, all three calculations were based upon a too-low value of the specific heat, a quantity increasing with temperature and also with the change of state from crystalline to vitreous.

The net result of these minor errors also is to find the earth cooler in depth than it really is.

Until more is known about the cause of the distribution of radioactivity in the rocks and about the rôle of delayed convection, it is impossible for the mathematician to declare finally the existing thermal gradient in depth. My own tentative estimates of temperature give 760° and 1330° at the respective depths of 30 kilometers and 60 kilometers; below the 60-kilometer discontinuity, temperatures everywhere so high as to prevent crystallization. While these estimates appear compatible with the principles of earth physics, I dare to put them before you, primarily because they portray a vital part of a theory of the earth which seems best adapted to account for the facts of geology.

Isostasy and the Vitreous Shells: If the earth has a true crust resting on a succession of vitreous, because hot, shells, the weakness of the glassy material automatically explains the sensitiveness of the crust to glacial loads, and in general accounts for the condition of isostatic balance among the larger topographic features of the globe. Supposing radioactivity to be proportioned to the acidity of the crust, the thickness of the crust and the densities of the outer segments of the earth should vary systematically. The result is a scheme of densities different from those of the Pratt and Airy explanations of isostasy. The preferred scheme can not, of course, be described in exact figures; an indefinite range of choices within the limits set by my theory is admissible. Nevertheless, a reasonable set of choices seems to be indicated, and I have found that the corresponding arrangement of densities reduces the gravity anomalies about as well as the Airy hypothesis does and better than the Pratt hypothesis, so commonly used by geodesists. (Illustrative diagrams of the address here omitted). Hence the explanation of isostasy implied by the crust-substratum idea seems to have some support from the pendulum studies so far made.

Evidence from Petrology: Gravitative differentiation of magma is evident in certain intrusive sheets, laccoliths, lopoliths, dikes, thick extrusive flows, and probably in visible parts of a few batholiths. Year by year new examples are being discovered. It is surely not a wild idea to think that the earth, from the bottom of the crust to the top of the iron core, is also stratified according to intrinsic (chemically determined) density. As in differentiated sheets, the density of the envelope of the core should not be expected to increase uniformly with depth. The analogies mentioned suggest rapid changes of density at more or less widely spaced levels. Between any pair of those levels the intrinsic density may be nearly constant.

Because of their high density the deeper shells should not be eruptible into or through the crust. Normally the one layer that does erupt, as if emanating from a continuous earth-shell, is the basaltic. From the Pre-Cambrian to the present day it has delivered at the surface great masses of basaltic liquid in every continental and oceanic sector. This liquid issues alone or in direct association (inside the time limits of the petrogenetic cycle) with magmas of different composition. Thirty years ago the hypothesis that such basaltic magmas have come from local pock-

ets of liquid in an essentially crystalline earth was held by some petrologists. But there is manifest difficulty in accounting for the pockets, whether as residuals of a planet once liquid, as locally developed eutectic solutions, or as local, radiothermal fusions. An increasing number of petrologists and geologists prefer the postulate that the erupted basalts originated in a world-circling, vitreous substratum.

Although not to be directly verified, this hypothesis has the advantage of explaining petrological and geodynamical facts more simply than any other yet published.

(1) In the first place, it enables us to understand why lava rises so high. The density relations expressed in Tables I and II are such that, if the crust is opened by a through-going fissure, the dead weight of the crust would tend to push up the substratum material at volcanic pipes to heights from three to six kilometers above sea-level.

(2) The hypothesis automatically accounts for the latent heat of the erupted, fluid basalts.

(3) Rising from a minimum depth of 60 kilometers, the basaltic liquid should be superheated. In fact the plateau-basalts, even after prolonged running and rapid radiation under the air, are still liquid to a degree apparently impossible if the flows started without superheat. If not superheated, could thin basaltic (diabasic, gabbroid) sills spread underground in their astonishing way?

(4) Without exception known to me, the earth's crust is basined where large volumes of basaltic magma were erupted at or near the surface, in the form of basaltic plateaus, or major cones, or lopoliths. The diameters of such structural basins measure hundreds of kilometers, a size suggesting that each erupted mass was transferred from a single, continuous earth-shell.

(5) The hypothesis seems to be the most adequate as a basis for deriving the origin of the 700 other species of post-Archean igneous rocks. Endowed with both latent heat and superheat, the erupted basaltic liquid is capable of melting and assimilating crust rocks, and these reactions, followed by differentiation of the syntectics, account for many of the non-basaltic species. On a particularly grand scale are the expected reactions and differentiations if large masses of the crust are thrust into, or founder in, the vitreous substratum.

The development of batholiths in orogenic belts was one of the earliest discoveries of earth science, and since Hutton's time has been accepted as proof of major, vertical displacement of melted rock. Why most batholiths are acid, granitic, is still a mooted question, but the best answer seems to be suggested by the twentieth-century proofs of extensive horizontal displacement of solid crust rocks towards each of the orogenic belts. This displacement is indicated by the arcuate ground-plans of the completed mountain-structures, by the nappe phenomena, and by the juxtaposition of geosynclinal facies originally distant from each other. Whether due to the earth's contraction or to the forceful, horizontal migration of independent blocks of continental size, each of the displacements involves an enormous addition of the solid material of the crust to the corresponding geosynclinal belt. The old view that this material or its equivalent volume of rock was locally piled up in excess on the earth's body, immediately giving each mountain-structure height to match, seems not to be in accord with the facts. For several young chains of mountains are still largely submarine, and others, somewhat older, attained their actual heights long after folding and thrusting had ceased. There appears to be only one alternative: the excess crust material sank into the earth's body at about equal pace with the orogenic paroxysm. In other words, the horizontal displacement of crust rock *towards* the geosynclinal belt was accompanied by vertical, downward displacement of crust rock *in* the belt. Such subsidence must be by downthrusting or downpulling, with the development of deep mountain roots; or by foundering of large pieces of the crust; or by both processes. If the material beneath the crust were crystalline and denser than the crust, neither downthrusting nor foundering on the required scale would be possible. Both are possible if the outer earth-shells are constituted as shown in Tables I and II.

Furthermore, it is worth noting that continental migration through the distances credited by Argand, du Toit, Heim, Holmes, Staub and Taylor, and even the horizontal displacements of the crust credited by Kober, who retains the contraction theory of mountain-building, are alike incredible unless the crust at each orogenic belt can sink deeply into a subcrustal layer. Hence, without assuming great weakness for this layer and also for it a density no greater than the mean density of the crust, both the contractionist and the migrationist are in trouble. Both are in still more trouble if they assume the horizontal displacement of crust rock to depend upon the horizontal scission, shearing, of strong crystalline rock from strong crystalline rock through the long distances and over the wide areas demanded. On the other hand, the resistance to such displacement is incomparably less if the crust moves over hot glass with the expected, little or no strength.

When there is strong horizontal displacement of the crystalline crust over the substratum, the crust yields at a geosynclinal prism. In part the roots of the mountain structure generated along that zone are due

to downwarping of Sial and crystallized Sima. In part the local crust is broken into huge blocks, which founder in the substratum. This process may be called *major stoping,* to distinguish it from the ordinary *piecemeal stoping* at batholithic contacts. Major stoping means the local invasion of the crust by extraordinarily great volumes of substratum material, which at the higher levels loses much of its viscosity and becomes more typically magmatic basalt. Thus we have *abyssal injection* of the crust and that at maximum.

The foundered blocks and the deeply sunken roots of the new mountains are heated by the substratum, in which the temperature increases downwards from about 1,300° to a higher temperature, fixed by the thermal gradient (perhaps in average as much as 10° per kilometer of descent for some distance). There the immersed crystallines are selectively fused. The first of the secondary liquids melted out of the basic rocks are derived from the minerals that go into mutual solution at comparatively low temperatures. Sialic rocks will undergo this *pure-melting* at temperatures well below even the lowest temperature of the substratum. On account of viscosity true abyssal assimilation will be subordinate to pure-melting, but is also to be considered. All derived liquids are less dense than the basalt of the main abyssal injections and rise through it, to invade the mountain roots, which already inclose chilled, solidified apophyses from the basalt. These more salic bodies, due to the self-cleansing of the primary basalt, are bottomless in the sense of lacking floors of crystallized rock. For them the name *major abyssoliths* (Greek, *abyssos,* bottomless) is proposed.

Thus one important class of batholiths is speculatively explained, though in my opinion the word "batholith" should be defined without reference to its mode of emplacement.

The imagined mechanism implies that the magmas invading the mountain-structure during the prolonged petrogenetic cycle should be in the general *eruptive sequence* from basic to acid—the order actually observed. It involves also the important principle of *resurgency,* that is, the rise of both liquids and gases that had belonged to the now melted and assimilated parts of Sial and Sima.

In comparison with basalt, acid rock shows a greater volume change in melting and almost certainly has a smaller latent heat. Hence, if pure-melting of Sialic rock takes place at the substratum levels, and if the resulting liquid rises high into the mountain roots, it must be *superheated* considerably more than the primary basalt, risen to the same high levels. Have we here a partial explanation of the "caustic," replacing action of many batholiths on the intruded formations? I ask this even though we have so little field evidence of superheat in flows of rhyolitic lava.

Syntexis (pure-melting plus assimilation) is, then, supposed to be largely concentrated in the substratum itself, but should be expected also at all higher levels within the masses of primary liquid injected into the crust. Sediments as well as older igneous rocks will be so affected.

The suggested scheme implies a genetic classification of nearly all of the igneous rocks (here omitted).

Some Objections: Finally, a word about certain arguments against the crust-substratum hypothesis. That supposed to derive from the high velocities of earthquake waves below the 60-kilometer level has lost practically all its force since Bridgman measured the compressibility of tachylite. The objection that the hypothesis implies danger of general catastrophic foundering of the crust fails to recognize the strength of the crust as ample security against that danger. Jeffreys, Joly, Richardson and Kirsch are others who agree with this judgment. Foundering occurs only where the crust rocks are wholly immersed in the substratum, but immersion is difficult and needs the coarse brecciation of the crust at orogenic belts.

The repeated objection founded upon the high rigidity of the outer shells is likewise fallacious. The actual rigidity is relative to the smallness and periodic character of the stresses set up by the passage of earthquake waves, the wave of the body tide and by the elastic reaction of the globe to the Eulerian nutation. The stresses persist for the limited times because of the earth's viscosity, a quantity all the greater because the stresses are small, as Adams and Williamson found when experimenting on hot glass. In any case, the proof of rigidity gives no information about strength, so that there is no evident ground here for doubting the vitreous state of the basaltic substratum and of the shells lying between it and the iron core.

CONCLUSION

We have briefly surveyed an old problem, weighted, as few others are, with fundamental meaning for geology. A problem it will long remain. Cosmogonic theory, seismological results, study of thermal gradients and of isostatic adjustment, like the multitude of facts of tectonics and petrology, all seem to support a thesis: Our planet is still too hot to crystallize at any depth greater than about 80 kilometers or 50 miles. But the support is not proof, nor is any theory of the earth to be absolutely demonstrated. As usual in the leading questions of science, we are pragmatists and search for the theory that works best. The thin-crust theory appears to work best. Yet the chief reason for putting it in the foreground is the fact that

it can guide to fruitful research in the future. As never before, the geologist realizes the meaning of the ancient maxim, "deep calleth unto deep," the need of seeking in the shells and core of the earth explanation for the dramatic changes registered in its relief and visible rocks.

A PROGRAM OF MEDICAL CARE FOR THE UNITED STATES

By Dr. C.-E. A. WINSLOW

PROFESSOR OF PUBLIC HEALTH, YALE SCHOOL OF MEDICINE; CHAIRMAN, EXECUTIVE COMMITTEE OF THE COMMITTEE ON THE COSTS OF MEDICAL CARE

IN every field of human activity we are to-day facing one common problem—the problem of adjusting our social order to the altered conditions produced by a revolution in technology. "Neither do men put new wine into old bottles; else the bottles break, and the wine runneth out, and the bottles perish: but they put new wine into new bottles, and both are preserved."

The traditional relationship between a physician and his patient, for example, was admirably adapted to the conditions of a century ago. It was indeed one of the finest and most fruitful examples of human relationship which one could well imagine. The physician practiced an art over which he had complete control and mastery. In his head he could carry all the knowledge then in existence and in his black bag all the paraphernalia available for the healing of the sick. His profession was a priestly mission, not a business. He cared for all who were in need of his ministrations. Those who could pay nothing paid nothing and those who could contributed in proportion to their means for the support of an honored servant of society. The physician and his patients were neighbors and friends. They knew each other intimately and for a lifetime, and the adjustment between service and recompense in a given case was made almost automatically.

This is, of course, an extreme statement of the actual situation; but it represents an essential ideal which underlay the relation between the doctor and his patient at the dawn of the machine age. It is a relationship which still exists to-day. Most of us know physicians and patients who maintain contact on the same elevated plane. Yet it would be safe to say that such a relation is rare and is becoming more rare with the passing of the years. This is due first of all to changes in medicine itself. The old art is now also a new science. No longer can one man understand it or practise it by himself. There must be specialists and consultants of many and diverse kinds (some twenty-five such specialties are now recognized). There must be well-equipped and costly hospitals. There must be nurses. There must be laboratories and laboratory technicians. There must be physiotherapy, devices of numerous kinds and special experts to use them. There must be x-ray machines and radiologists.

Equally fundamental in their influence upon the older ideals of medical practise are the changes produced by technology in the general social order itself. The old neighborhood life has gone and with it the intimate and prolonged personal contacts which made the old relationship between physician and patient simple and easy of attainment. Still more deeply is this relationship affected by the subtle forces of a society dominated by the profit-motive in which as John Dewey has pointed out in "Individualism Old and New," old motives of social responsibility have disappeared and new ones have not yet been developed to take their place The physician finds himself half priest and half business man, a servant of society in a world which has ceased to recognize service except as measured by financial return, a business man in a field where the fundamental requirements of basic human need preclude the application of ordinary principles of economic individualism.

It is characteristic of the forces which dominate our civilization that the impulse which actually precipitated a broadly conceived study of this vital social problem was largely an economic one. It was primarily wide-spread complaint of the financial burden of illness on the one hand and legitimate dissatisfaction on the part of the professions and agencies furnishing medical service on the other which led to the formation on May 17, 1927, of the Committee on the Costs of Medical Care. From the first, however, the committee realized that it was impossible to consider costs without considering quality as well and it has set as its ultimate goal the "development of preventive and therapeutic services in such kinds and amounts as will meet the needs of substantially all the people" and the provision of such services "on financial terms which the people can and will meet, without undue hardship, either through individual or collective resources."

The committee, which made its final report on December 29 last, was composed of 48 members under

the chairmanship of Dr. Ray Lyman Wilbur. Twenty-five of its members held the degree of doctor of medicine. Analyzed in another way, seventeen were private practitioners of medicine and dentistry, ten were representatives of institutions and special interests, six were public health workers, six social scientists and nine representatives of the general public. Funds for research were obtained through the generosity of eight foundations, and many other agencies have cooperated whole-heartedly in the conduct of special studies. An administrative staff was organized under the leadership of Harry H. Moore, whose vision has throughout been the inspiring force in the work of the committee. A brilliant research staff under I. S. Falk has been responsible for the actual conduct of the detailed investigations. The studies have been completed on schedule time (an almost miraculous result!) and have been published in 27 volumes.[1] The twenty-eighth and final volume, "Medical Care for the American People," is the report of the committee itself, signed by 35 of the 48 members of the committee. Minority reports were presented by two groups (one of eight physicians and an institutional representative, the other of two dentists) who find the report of the committee too radical; special minority statements were presented by a public health worker and a social scientist who find it too conservative.

In analyzing the findings of the committee it will be well to begin with one study which has received as yet but little attention but which should ultimately prove of far-reaching significance. This is Report No. 22 on "The Fundamentals of Good Medical Care," by Roger I. Lee and L. W. Jones. It gives us first an analysis of the number and kinds of illnesses to be cared for in the United States, second, an estimate of the amount and kind of medical care (home and office visits, laboratory tests, x-rays, days of hospital care, etc.) required by the average illness of each type. From these data the number of general practitioners, specialists, dentists, nurses, hospital beds, etc., needed for a given population are then computed. These analyses lead to the encouraging conclusion that a slight increase in medical personnel (with a considerable decrease in specialists), a very slight increase in nurses, and a considerable increase in dentists would be needed to meet the ideal needs of the American people for complete and adequate medical care. With proper organization they estimate that such complete care (preventive and curative, including effective health service and all nursing and hospital costs and charges for drugs) could be provided at an average cost of $36 per person per year.

The actual expenditure of the American people for medical care is to-day very close to this sum—$3,656,000,000, or $30 per capita; but the actual service rendered is very far from the adequate care which could be purchased for such an amount. The committee has obtained a remarkably clear picture of the existing situation. It has first of all (in Study 26) made a study of medical costs during a twelve-month period in nearly 9,000 families, representing various geographical areas and various economic levels; and it has supplemented this by intensive studies of community facilities in Shelby County, Indiana, the city of Philadelphia, the city of Detroit, San Joaquin County, California, the state of Vermont, and three representative southern counties (studies 6, 9, 10, 12, 13 and 23). These investigations reveal the following outstanding deficiencies in the present status of medical care.

A. *Maldistribution of facilities in various geographical areas.* These may be illustrated by the fact that in 1929 there was one physician to every 1,431 persons in South Carolina and one to every 571 in California; one dentist to every 5,274 persons in Mississippi, and one to every 990 persons in Oregon; one hospital bed to every 749 persons in South Carolina and one to every 154 in Wisconsin. Conditions in the Southern states are nothing less than appalling.

B. *Maladjustment of services in all areas.* In the rural areas, even where general practitioners are available, there is grave lack of hospital and laboratory facilities and of consultation service; and even in cities many physicians lack the hospital connections which would make the most effective work possible. On the other hand, the cities as a whole show a markedly excessive development of specialization. Forty-five per cent. of the physicians of the country have completely or partially limited their practise to a specialty, where we estimate that 18 per cent. would suffice for the real needs of the situation. Some patients suffer from lack of specialist service and some from too much.

C. *Waste in the provision of service.* There is wide-spread waste of time and of overhead costs in the rendering of service on an individual basis. About 40 per cent. of the average physician's income is consumed in overhead expense. The average physician also, particularly in the years immediately following graduation, wastes a large part of his time in waiting for patients, while the older man with unusual capacity in some particular field wastes much of his time in routine functions that a younger man could perform quite as well.

D. *Unwise expenditures for medical care.* Of the total of $3,656,000,000 a year now spent by the American people for medical care, 360 million dollars go for "patent medicines" and 125 million dollars for the services of cultists and irregular practitioners who

[1] The University of Chicago Press.

have never studied the human body and do not understand its working.

E. *Economic burden of emergency illness.* The average expenditure of $30 per capita per year does not seem exorbitant. It amounts to about 4 per cent. of the national income, less than we pay for household furnishings and supplies, less than half we pay for automobiles and only slightly more than we pay for recreation or for education or for tobacco, confections, ice cream and soft drinks. Such an average, however, gives no picture whatever of the actual situation. The other items mentioned can be predicted and budgeted; but sickness can not. Our studies bring out the astonishing fact that in the group of families with incomes under $2,000 a year (about half the population of the United States) one per cent. of the families spent over $500 in one year for medical care. It is this hundredth family (over one million of them in the United States in a given year) which contributes from one quarter to one half of its annual income to meet the emergency cost of illness which constitutes the critical economic problem in the field of medical care.

F. *Inadequate compensation for persons and agencies providing service.* One result of such economic maladjustment is that the compensation of the individuals furnishing service is on the whole inadequate and uncertain. The average net income of physicians in 1929 was $5,300, which may or may not be considered reasonable; but the median net income was only $3,500, and one third of all physicians had net incomes below $2,500. Private duty nurses were in a desperate situation even prior to the depression. Voluntary hospitals in many areas are now in serious danger of being forced to close their doors.

G. *Inadequate care of the sick.* The second result of economic maladjustment is that a shockingly large amount of illness is now actually uncared for (in spite of the potential adequacy of the resources at our disposal). The table below presents some of the most disturbing facts brought out in our study.

Clearly, the common catchword that "only the very rich and the very poor receive good medical care" is only half true. The very rich are reasonably well cared for (except for dentistry) and have slightly more special nursing than they need; but as one goes down in the economic scale the adequacy of care becomes less and less, except that the very low income levels receive more hospital care than those in the middle range. The lower half of the population (below $2,000 annual income) receive only a little over one third of the physicians' visits, less than two thirds of the hospital care, a little over one tenth of the dental care and a little over one tenth of the special nursing care required.

H. *Lack of preventive services.* Finally, there is everywhere a grave lack of the applications of modern medical science to the prevention of disease. We talk about preventive medicine and annual health examinations, but we do not practise them. As long as preventive services are immediately contingent on the payment of a fee for such services they can not be urged by the physician and they will not be sought by the patient.

	Services received in families with specified incomes						Services required by standards of good medical care
	Under $1,200	$1,200–$2,000	$3,000–$5,000	$5,000–$10,000	Over $10,000		
Physicians' home, office and clinic calls per person	1.9	2.0	2.3	2.7	3.6	4.7	5.6
Days of hospital care per person	0.9	0.7	0.8	0.6	0.8	1.2	1.4
Dental care, per person over 3 years of age	0.1	0.2	0.2	0.3	0.4	0.6	1.0
Cases receiving special nursing care per hospitalized case	0.1	0.1	0.2	0.3	0.4	0.7	0.6

So much for the defects in the operation of the general machinery for the provision of medical care to the American people. A second group of studies made by the committee deals with a very different picture found in certain special population groups where experiments have been made in providing medical care on a different basis through organized social planning. Reports have been presented on four different types of services of this kind—industrial medical services providing medical care for employees and their families, conducted by the Endicott-Johnson Company, the Homestake Mining Company and at Roanoke Rapids, North Carolina (Nos. 5, 18 and 20); university medical services at California, Cornell, Michigan, Oregon and Yale (No. 19); service provided for officers and men and their families at an army post at Fort Benning, Georgia (No. 21) and service provided by tax-supported physicians in the rural areas of Saskatchewan (No. 11).

It must not be inferred that the committee presents these instances as necessarily typical of industrial or military or other forms of organized medical care. The programs studied were chosen because they were believed to be good examples and they are significant,

not necessarily as pictures of average organized practise to-day, but as illustrations of what organized practise can accomplish when properly safeguarded.

From this standpoint, the experiments reviewed are highly encouraging. They show us representative population groups which under an organized program are receiving a type of medical care which is free from practically all the limitations operating in the country as a whole. The beneficiaries of these services are receiving a far greater amount of medical care and medical care on the whole of better quality than corresponding economic groups in the general population. The expense of the service provided varies according to its completeness. The rural service in Saskatchewan which covers only home and office calls by physicians costs only about $2 per person per year. That at Homestake which does not cover dentistry or home nursing costs a little over $12. The highly developed and practically complete services of the Endicott-Johnson Company, the Fort Benning Post and the better equipped universities costs from $20 to $30 per person per year. In other words the actual cost corresponds very closely to the average expenditures of the general population at a corresponding economic level; but the service is something like twice as extensive. At Roanoke Rapids, for example, the mill population paid for their organized service $8.72 per capita per year as against $5.17 paid by the rest of the community (the latter being on a slightly higher economic level); the mill group, however, received three times as much hospital care, nearly twice as many physicians' office and home calls and ten times as many home nursing calls as did their fellow townsmen. At Homestake the organized group provided for $71,000 service which at current local rates would have cost $175,000.

The increased values obtained from organized service, in such instances as those cited, are not in any sense derived from exploitation of the professional personnel concerned but by elimination of waste time and needless overhead charges. The salaries of physicians in Saskatchewan and in the industrial and university service cited are well above the average for similar areas, and in general for the country as a whole.

The funds are obviously derived from various sources—from the tax levy in Saskatchewan and at Fort Benning, from the students in the universities, from employer or employee or both in the industries. In all instances, however, payment by the potential patient is on a fixed annual or monthly basis, so that the crippling burden of emergency illness is eliminated. Finally, as the Saskatchewan doctors and the industrial physicians testify with particular emphasis, the removal of the pecuniary inhibition in connection with a particular service makes it infinitely easier on both sides to offer and to receive medical care of a preventive and therefore really fruitful kind.

These investigations have, then, led the committee to its two major recommendations. The first of these is "that medical service, both preventive and therapeutic, should be furnished largely by organized groups of physicians, dentists, nurses, pharmacists and other associated personnel. Such groups should be organized, preferably around a hospital, for rendering complete home, office and hospital care." The chief difficulties which the committee believes can be overcome by group practise are listed as follows:

> The lack of coordination between general practitioners and specialists; the isolation of some practitioners from helpful contacts with their confrères and from hospitals and medical agencies; the lack of adequate supervision and control over the quality of some medical care; the enforced idleness of many physicians because of lack of patients; the difficulty experienced by patients in choosing qualified physicians; the unnecessarily large expenditure for overhead costs made by practitioners in individual private practice; and the increasing complexity of medical service which necessitates the use of ever-multiplying equipment, as well as a larger number and variety of subsidiary personnel.

Secondly, the committee recommends "that the costs of medical care be placed on a group payment basis, through the use of insurance, through the use of taxation; or through the use of both these methods." The argument here is, of course, obvious and inescapable. Only by distribution of costs over a period of time and over a group of families can the crippling economic burdens of emergency illness be avoided. Only by such distribution of costs on a fixed annual basis can the general use of preventive measures be brought within the range of practical possibility.

The ideal of the committee is the development in urban areas of community medical centers organized about existing hospitals. In some instances these would be city or county or town hospitals (particularly in rural areas). More often they would be voluntary hospitals, directed as our non-official hospitals are to-day by a lay board representing community interests. Practically all the physicians, dentists and private duty nurses in a community might be on the staff of one or another of the hospitals, and these staffs would be organized as those of our best hospitals are to-day, so that qualified chiefs of services would be responsible for the quality of service rendered. All professional policies would be directed by the professional groups concerned. Complete preventive and curative care of all types, in home, office and ward, would be provided for one fixed annual

fee. The majority of physicians on the staff would be general practitioners and the individual would choose his own family physician with complete freedom among those available in the centers within his reach.

Such completely equipped centers might serve more than 50 per cent. of the American people who live in communities of over 15,000 or within reach of them. For smaller isolated towns (about 10 per cent. of the population) small branch hospitals could be used, affiliated with the larger centers for consultation service and for the handling of specially difficult cases. For the villages and rural areas (including slightly less than 40 per cent. of our population) still smaller "medical stations" should be established with one or two physicians, a dentist, a trained nurse-midwife and other public health nurses. They would rely upon medical centers or branches for facilities and service they could not themselves supply and would be visited at intervals by specialists from such centers.

The method of accumulating the collective reserves to pay for services would differ with local conditions. In remote rural areas the tax levy (as in Saskatchewan) would seem to be the only promising source. For the indigent in all areas the tax levy would necessarily provide, as it does (inadequately) at the present day. In industrial communities the employer might properly contribute his share, as he often does now. It seems highly desirable, however, for the development of a due sense of personal responsibility that as large a proportion as possible of the costs of medical care should be borne by those who are to receive that care—in other words, by payment from individual families through the medium of an insurance plan.

This is the method which has been universally adopted by the nations of western Europe (in contradistinction to the tax-supported state medical service of Russia and certain other countries of eastern Europe); and, in general, these nations have moved steadily forward from experiments with voluntary group purchase to programs of compulsory state insurance. The committee is nearly unanimous in recognizing that complete coverage of all those who require care can only be ultimately attained in the United States by a system of compulsory insurance. If and when such a program is adopted we trust that insurance for medical care may be sharply and completely separated from insurance covering wage losses due to illness, since we feel that the difficulties experienced in Europe have been largely due to confusion between these two different objectives.

The majority of the committee is not, however, prepared to recommend compulsory sickness insurance in any form at this time—chiefly for the following reason. We do not believe that adequate medical care can ever be provided by private physicians operating on a purely individualistic basis, and if the introduction of compulsory insurance crystallized and fortified the present system of medical practise, we believe that the dangers would outweigh the benefits. We should like, therefore, to see a period of experimentation with voluntary group purchase going hand in hand with the development of group practice so that when compulsion comes the public can contract with well-organized and well-established medical centers and their cooperating agencies. We can begin with industrial groups, church groups, neighborhood groups and other voluntary aggregations, while we are gaining experience in medical organization and in actuarial practise; and that this is not an idle dream is shown by experience in England, where something like six million people are now insured for hospital care in voluntary groups.

The report of the Committee on the Costs of Medical Care has already, in the brief time since its appearance, been subjected to very vigorous criticism. This is highly encouraging, since only platitudes receive easy and general acceptation. Many of these criticisms, however, are obviously made by those who have never read the report, since they condemn it for positions which it does not imply in any shape or form.

We have, for example, been charged in supposedly serious scientific quarters of advocating socialism and communism and of "inciting to revolution." Yet the entire program advocated by the communite is based primarily on group practise in voluntary hospitals and on group purchase by privately organized bodies of citizens. The tax levy is only brought in for rural areas where there is no other source of funds and for the support of the indigent which is already a universally accepted form of socialism. We believe that the policy we have proposed is the only way of forestalling a type of state action which has become almost universal in Europe and which will be inevitable here if such forms of voluntary group planning as we have suggested can not be successfully evolved.

A second ground of opposition to the report is that it advocates a type of group service called by the medical profession "contract practise" which may readily be made the agency of "unfair competition." Here, the whole question hinges on what is meant by "unfair competition." If a group of physicians render a substandard type of service there is certainly unfair competition with their professional confrères. If, on the other hand, a group of physicians is exploited through overwork or underpayment by an industry or some other agency organizing a group, there is unfair competition. Either of these conditions will injure both the public and the profession and should be strongly condemned. But if it be found (as it has

often been found) that a group of physicians can receive ample compensation and yet furnish equivalent care to patients at lower cost than can their individual colleagues in the community, we have a different story. The advantages of group practise which accrue directly from the organized nature of that practise are clearly in the interest of both the profession and the public. No condemnation of "unfair competition" which is based only on such advantages can ultimately be maintained.

Opposition to the plans of the committee is also based on the fear of "lay control" of medical practise. The committee is quite at one with such critics in stating clearly that "lay groups organized for profits have no legitimate place in the provision of this vital public service." On the other hand, it is apparent that in a "vital public service" there are vital public interests at stake. Medicine can not to-day be practised without large capital sums invested in hospitals, laboratories and clinics; and the public must continue to have its voice in the management of such institutions. The combination of a lay board representing the public interests involved and a professional staff in full control of professional policies seems to offer the only rational solution of the problem.

Finally, there is the fear that group practice and group purchase would mechanize medicine and wipe out the essential personal relationship between physician and patient. There is no doubt that this has happened in some group practices, and there is no doubt that where it does happen it is destructive of the essential basis of good medical care. There is no reason, however, why it should happen. It does not appear to have happened in the university and industrial services we have studied or at Fort Benning. It does not happen in many of our best clinics where the appointment system is coming into use. In a properly organized medical center such as we have described the relation between family physician and patient (which has so largely disappeared from private practice in urban centers) could be restored to a new importance and dignity and freed from the constant inhibitions on both sides which are due to the intrusion of the element of pecuniary responsibility at every stage in what should be a free personal relationship.

The committee does not of course recommend the immediate completion of its program on any general scale or indeed in any given community. It does endorse the principles of group practice and group purchase as basic in any sound program of advance; but it recognizes that local differences—social, economic, geographical, psychological—will make widely differing applications of these principles desirable.

The committee recommends "that the study, evaluation and coordination of medical service be considered important functions for every state and local community, that agencies be formed to exercise these functions, and that the coordination of rural with urban services receive special attention." It urges experimentation in the direction of expanding existing institutions, hospitals, group clinics, pay clinics, industrial and university medical services and the like. To readers of SCIENCE it may be of particular interest to note the recommendation that

> The student health services, found feasible in certain universities, may be extended to other universities and academic institutions, and the services made available on a suitable periodic payment basis to faculty members and their dependents and to other university employees and their dependents. In "college towns" it may frequently be feasible to expand the university medical service into a community medical center which serves townspeople as well as students.

To quote again,

> The aim should be to adopt objectives which at present seem sound, and to develop definite and purposeful experimental methods of approaching those objectives, preserving, insofar as it is compatible with effective service, the maximum amount of local self-support, and self-control, and the greatest freedom, consistent with social welfare, for the professions and the agencies involved. Although too great decentralization of authority limits competence and threatens economic effectiveness, too great centralization of authority in any plan carries with it elements of ultimate weakness. Fortunately, we have retained in this country a wholesome local responsibility for medical service. This fact means that opportunities exist for trying out many plans under various and variable conditions. Where action can be limited to the city or county, we have several thousand experiment stations. If state action is necessary, there are forty-eight laboratories.

Experimental social planning along sound theoretical lines, but based on existing American institutions —this is the objective set before us for the solution of the economic problem of medical care.

OBITUARY

ORMOND STONE

1847–1933

AFTER living to the ripe age of eighty-six years, Professor Ormond Stone was instantly killed on January 17 near his home in Centreville, Virginia, when struck by an automobile while he was walking along the road. With his passing, the University of Virginia loses its oldest professor and astronomy a noted figure.

He was born in 1847 in Illinois and he received the M.A. degree from the University of Chicago. For five years he was at the U. S. Naval Observatory in Washington and left there in 1875 to go to the Cincinnati Observatory as director. When Leander McCormick, the son of the inventor of the famous reaping machine, gave to the University of Virginia the 26-inch refractor, the telescope was the largest and the finest in the world. In looking for a director, the distinguished astronomer Simon Newcomb recommended for the position the director of the Cincinnati Observatory. For thirty years, from 1882 to 1912, when he was retired on the Carnegie Foundation, Professor Stone directed the work of the McCormick Observatory. No photographic work was attempted, but valuable visual observations were made on double stars, variable stars, nebulae, the satellites of Saturn, etc. In addition, he observed three total solar eclipses, that of 1869 in Iowa, he was in charge of the Naval Observatory expedition to Colorado in 1878 and of the McCormick expedition to South Carolina in 1900.

Professor Stone was as much at home in the field of mathematics as he was in astronomy. He was the founder and the first editor of the *Annals of Mathematics,* later taken over by the American Mathematical Society.

The Vanderbilt fellowships at the University of Virginia attracted to the McCormick Observatory many capable young men. Among those now living who hold the degrees of doctor of philosophy from Virginia and who have attained prominent scientific positions are the following: Edgar Odell Lovett, president of Rice Institute; Heber D. Curtis, director of the University of Michigan Observatory; Charles P. Olivier, director of the Flower Observatory; Herbert R. Morgan, U. S. Naval Observatory; Ralph E. Wilson, Dudley Observatory; G. F. Paddock, Lick Observatory, and T. McN. Simpson, Randolph-Macon College.

The combination of a great telescope and skill as a mathematician brought distinction to the University of Virginia. Naturally the McCormick telescope did not long remain the largest in the world. Four years after its opening, the Lick telescope of 36-inch aperture was dedicated.

Professor Stone came of a prominent family. He was a brother of Melville Stone, for many years general manager of the Associated Press.

S. A. MITCHELL

ARTHUR GRAY LEONARD

DR. ARTHUR GRAY LEONARD, professor of geology at the University of North Dakota and state geologist for thirty years, died at his home in Grand Forks on December 17, 1932. He was born at Clinton, New York, March 15, 1865. He graduated from Oberlin College in 1889, received the degree A.M. from his alma mater in 1895 and the Ph.D. degree from the Johns Hopkins University in 1898. He served as assistant state geologist of Iowa, assistant professor of geology at the University of Missouri and professor of geology at Western College before going to the University of North Dakota in 1903.

The wide range of Dr. Leonard's contribution to the knowledge of the geology of North Dakota is indicated by the titles of his numerous geological papers in scientific journals and the reports of the United States Geological Survey and the North Dakota Geological Survey on such subjects as lignite coal, clay, gravel and the possibilities of oil and gas. A complete list of his publications numbers over fifty.

Dr. Leonard's greatest contribution to the science aside from that as a teacher was his addition to the basic knowledge of the geology of lignite coal, its origin and the relation of the lignite-bearing beds to the geologic time scale.

HOWARD E. SIMPSON

JOHN F. G. HICKS

THE many friends and former students of Dr. J. F. G. Hicks will regret to learn of his death on December 13, at his home in Portland, Oregon. At the time of his death he was teaching in the Institute of Technology Junior College in Portland. His health failed while he was doing research at the Bureau of Standards on paper deterioration (1929–1931).

Dr. Hicks was born in Philadelphia in 1884. He received his B.S. degree from the University of Pennsylvania in 1906, and his M.S. and Ph.D. degrees from the University of Illinois in 1916 and 1918, respectively.

Besides holding several industrial positions, Dr. Hicks held professorships in the departments of chemistry of Oregon State College, University of Nevada and North Pacific College. At the time of his death he was actively engaged in writing a textbook of chemistry.

RALPH W. HUFFERD

RECENT DEATHS

CHARLES G. FAIRCHILD, formerly professor of physics at Oberlin College and later president of Rollins College, died on January 20, at the age of eighty-nine years.

DR. WINFIELD S. DUDGEON, professor of botany at Ewing Christian College, Allahabad, India, died at Ames, Iowa, on December 26, at the age of forty-six years. Professor Dudgeon had been spending a sabbatical year in the United States.

DR. JOHN H. STUMBERG, a member of the research staff of the Rockefeller Institute at Princeton, died suddenly on January 20, at the age of twenty-six years.

Nature announces the deaths of Professor Paolo

Enriques, professor of zoology in the University of Padua and president of the last International Congress of Zoology, and of Professor James Johnstone, professor of oceanography in the University of Liverpool, formerly director of the Marine Biological Station, Port Erin.

SCIENTIFIC EVENTS

INVESTIGATION OF THE CARIBBEAN REGION

ARRANGEMENTS have been made between Yale University and the Woods Hole Oceanographic Institution for a continuation of the cooperative program of marine investigations in the Central American seas, which was inaugurated by the Yale Oceanographic Expedition to the Gulf of Mexico on the schooner *Mabel Taylor* last year. The research ship *Atlantis,* belonging to the institution, is now being equipped for a three-months oceanographic cruise in the Caribbean, and is expected to leave Woods Hole at the beginning of February.

A series of observations will be made from Woods Hole to Bermuda and from Bermuda to Nassau, Bahamas, from which point the joint investigations take their start, with Professor A. E. Parr, curator of the Bingham Oceanographic Collection at Yale University, and a research associate of the Woods Hole Oceanographic Institution, in charge of the subsequent scientific work in the Caribbean waters.

The contemplated investigations will be chiefly concerned with the general oceanic circulation in the Central American seas, particularly as it affects the transportation of water from the inflow of the North Equatorial current through the passages between the Windward Islands at the southeastern end to the outflow of the Gulf Stream through the Straits of Florida in the North. Special attention will also be given to the problem of the origin of the cold bottom water in the isolated chains of deepsea basins extending through the Gulf and Caribbean region. It is hoped that the results of the coming cruise, combined with the observations from last year's expedition to the Gulf of Mexico, may prove sufficient to give a general outline of the oceanographic conditions throughout the Central American Seas on which further investigations can be based.

Along with the hydrographic observations, biological material will also be collected, and an attempt will be made to obtain an idea of the frequency of the larger deepsea animals by the use of a triangular otter trawl of much greater opening width than that of any gear previously employed for deepsea collecting.

NATIONAL FELLOWSHIPS AT THE JOHNS HOPKINS UNIVERSITY

UNDER the National Fellowship Plan of the Johns Hopkins University, Baltimore, Maryland, three $1,000 fellowships for graduate study of chemistry at the university will be open to qualified students in colleges and universities this year. The three are the Francis P. Garvan Fellowship for New York, the H. A. B. Dunning Fellowship for Maryland and the Eli Lilly Company Fellowship for Indiana. The New York and Maryland fellowships have been endowed by their donors, while the Indiana fellowship has been renewed for a period of four years. The fellowships provide the student $1,000 annually for a period of four years.

The purpose of the National Fellowship Plan is described as "the selection and training of chemists who are especially fitted to contribute to fundamental chemical progress"; and, under the plan, thirty-two men, representing thirty-two states, are now pursuing research on the grounds at the Johns Hopkins University. Their work covers a wide variety of fields.

The fellowships, providing $1,000 annually for a period of four years, give the recipients an opportunity for fundamental training and original research in chemistry and related subjects. The four major branches of chemistry, inorganic, organic, physical and analytical, are studied, and an elective system of study is followed by the student. In addition to the fundamental curriculum, the students are given an opportunity for personal contact with leading European and American chemists, through a visiting lectureship which has been provided by Dr. A. R. L. Dohme, of Sharpe and Dohme, Baltimore.

The selection of the successful candidate is accomplished through state committees which evaluate the student's complete previous scholastic record, and his personal qualities as rated by his instructors. Students in the sophomore, junior and senior year of the colleges and universities of the designated state are eligible for the fellowships. The successful candidates will be notified on or before April 1, 1933, and will begin their work at the Johns Hopkins University in October, 1933.

FORMAT OF THE PHYSICAL REVIEW

The Physical Review, together with the other journals published by the American Institute of Physics, has adopted a new style and format, with two three-inch columns on the page as in SCIENCE. It was chosen in a conference of all the editors. The advantages of the new format are said to be the following:

Economy. For a given amount of reading material,

less paper is used and fewer press operations are required. The saving is considerable.

Readability. The short line is recommended by authorities as being more easily and quickly read. This is based on reading tests. In proofreading this issue, the editorial staff accomplished the task with much less time and effort than heretofore.

Adaptability. The larger two-column page permits adapting cuts, tables and formulas either to the three-inch or the six-inch width. There is less waste white space at the sides of such material. The page is thus more uniform in appearance as well as more economical. Large cuts and tables may now be displayed properly instead of having to be turned lengthwise on the page.

Convenience. More material is presented on each page. Two open pages are the equivalent of three or more pages of the old format. Scientific reading requires frequent references to tables and figures. There will now be less necessity to turn pages in consequence.

Bound Volumes. Because of the more efficient use of paper, the bound volumes will be lighter. They will be slightly higher, but not too high for ordinary shelving. They will be thinner and so require less shelf space.

THE JOURNAL OF CHEMICAL EDUCATION AND THE CHEMISTRY LEAFLET

Industrial and Engineering Chemistry reports that certain changes, in effect January 1, 1933, have been made in the editorial and business departments of the *Journal of Chemical Education* and *The Chemistry Leaflet*. A signed statement by Lyman C. Newell, chairman of the Division of Chemical Education, appears in the current issue of the *Journal of Chemical Education,* and is essentially as follows:

The withdrawal of financial support by the Chemical Foundation has necessitated certain changes in the editorial and business departments of the *Journal of Chemical Education* since its last issue. Neil E. Gordon has resigned as editor-in-chief and William W. Buffum as business manager. Otto Reinmuth is continuing as editor and Harvey F. Mack has been appointed business manager.

The impending reduction, and possible withdrawal, of the financial support which the Chemical Foundation so generously maintained for several years led to the appointment of a special committee at the Denver meeting of the division on August 22, 1932.

The special committee rendered its final report to the executive committee early in December, and the report was accepted.

When the special committee met on October 8 to consider the situation and formulate plans, it was learned that the Chemical Foundation could no longer grant financial aid for the *Journal of Chemical Education* and *The Chemistry Leaflet,* nor for the activities of the division. Prompt and drastic action was imperative. The result of meetings and conferences of the special committee is substantially as follows:

The ownership of *The Chemistry Leaflet* has been returned to Pauline Beery Mack, who convinced the special committee that she could continue its publication.

After extended efforts to find ways and means to continue the publication of the *Journal of Chemical Education* it was finally decided to accept the proposition of the Mack Printing Co., whereby the division shall continue to own and edit the *Journal of Chemical Education* and the Mack Printing Co. shall assume the business management and financial responsibility.

Neil E. Gordon's resignation as editor-in-chief has been accepted by the executive committee. The editorial office has been removed to Easton, Pennsylvania, where Otto Reinmuth continues to act as editor.

In accordance with a recommendation of the special committee, the supervision and general control of the affairs of the *Journal of Chemical Education* will be lodged in a board of publication. Many details are being worked out by this board in cooperation with the editorial and business departments. Further announcements of details will be made in future numbers of the *Journal of Chemical Education.*

The Chemistry Leaflet continues in the same style, but the *Journal of Chemical Education* has a new cover, page size, style and topography. The general editorial policy of each publication will not be altered.

DINNER IN HONOR OF EDWARD BAUSCH

EDWARD BAUSCH, president of the Bausch and Lomb Optical Company, was the guest of honor on January 23 at the annual dinner of the Society of the Genesee, an organization of men and women who have lived in the Genesee Valley of New York State and who meet each year to honor an outstanding neighbor and renew old friendships. The annual dinners have been held in New York for many years and many notable men have been honored.

The speakers included Major General James G. Harbord, chairman of the board, Radio Corporation of America; Dr. Arthur L. Day, head of the Geophysical Laboratory, Carnegie Institution, Washington, D. C.; Dr. Rush Rhees, president of the University of Rochester, and Louis Wiley, business manager of *The New York Times.* President Elon H. Hooker was toastmaster.

A correspondent writes:

Edward Bausch is one of America's early microscope builders, starting when there were only eighteen microscopes in the entire country. He designed instruments and devised methods of producing them in sufficient quantities so that they could be sold at a low price.

Edward Bausch was born September 26, 1854, the oldest son of John Jacob Bausch, manufacturer of spectacle lenses and hard rubber frames. Edward built his

first microscope while he was still in school. Before he completed his college course at Cornell University he was called home by his father to take over some of the responsibilities of the optical business.

The Bausch and Lomb Optical Company started manufacturing microscopes soon after Edward Bausch joined the company in 1874. Their microscopes won prizes at the Centennial Exposition in 1876 and were soon being produced in quantities for use in science courses in schools, and the laboratories of hospitals and research institutions. They added microscopic accessories and developed other scientific optical instruments until now they make thousands of different optical devices for use in science, industry, education and medicine.

Edward Bausch has been a leader in the invention of optical equipment and the development of mechanical means for producing it at a reasonable cost. He was born only a stone's throw from the Genesee River and has spent his long life building the enormous Bausch and Lomb Optical Company plant upon its banks. While his neighbors honor him for what he has done in the community as a man, the nation remembers him for his scientific achievements during this seventy-ninth year of a long and useful life.

SCIENTIFIC NOTES AND NEWS

THE British Royal Astronomical Society has awarded its gold medal for 1933 to Dr. V. M. Slipher, director of the Lowell Observatory, Flagstaff, Arizona, for his spectroscopic researches on planets, stars and nebulae. Dr. Slipher has been invited to deliver the George Darwin Lecture this year.

THE University of Wales has conferred the degree of D.Sc. on Dr. Francis E. Lloyd, professor of botany in McGill University, and on Professor Robert Robinson, Waynflete professor of organic chemistry in the University of Oxford.

DR. C. JUDSON HERRICK, professor of neurology at the University of Chicago, was recently tendered a dinner given by a group of his colleagues in celebration of the twenty-fifth anniversary of his professorship.

DR. CHEVALIER JACKSON, professor of bronchoscopy and esophagoscopy at Temple University, has been awarded the medal of honor of the Italian Government by the King of Italy.

ACCORDING to *Nature* the Government of Ecuador has awarded the decoration of *Al Merito,* in the degree of Gran Oficial, to Dr. George Sheppard, state geologist to the Republic of Ecuador.

PROFESSOR WILHELM SCHÜFFNER, director of the Institute for Tropical Diseases, Amsterdam, has been awarded the Hans Aronson Foundation Prize.

THE Buchan Prize of the Royal Meteorological Society for 1933 has been awarded to David Brunt, for papers contributed to the *Quarterly Journal* and *Memoirs* of the society during the years 1927–31.

THE Bavarian Academy of Sciences has awarded the gold *Bene merenti* medal to Dr. Herman Strebel, in appreciation of the gift of his observatory at Ammersee to the State Observatory.

DR. WILLIAM H. PARK, director of laboratories for the New York City Department of Health, has been appointed to the Hermann M. Biggs professorship of preventive medicine at the New York University and Bellevue Hospital Medical College. The Biggs professorship was made possible by a memorial fund established shortly after his death in 1923 and recently increased to a total amount of $200,000 by a bequest of Mrs. Hermann M. Biggs and gifts from William R. Biggs and Mrs. Katherine Biggs McKinney, son and daughter of Dr. Biggs, and the Milbank Memorial Fund.

DR. A. B. LUCKHARDT, chairman of the department of physiology of the University of Chicago, has been elected honorary president of the International Anesthesia Research Society.

HOWARD COONLEY, president of the Walworth Company, New York, has been elected to the presidency of the American Standards Association for the year 1933. F. E. Moskovics, chairman of the board of directors of the Marmon-Herrington Company, Indianapolis, has been elected vice-president.

DR. CHARLES H. MAYO, of the Mayo Foundation, Rochester, Minnesota, has been elected president of the Minnesota Public Health Association.

DR. RALPH S. LILLIE, of the University of Chicago, was recently appointed an advisory trustee of the International Cancer Research Foundation.

L. V. COLEMAN, director of the American Association of Museums, has become a member of the American National Committee on International Intellectual Cooperation of the League of Nations.

MR. H. T. TIZARD, rector of the Imperial College of Science and Technology, London, has been appointed chairman of the Aeronautical Research Committee in succession to Sir Richard Glazebrook.

MR. C. F. A. PANTIN, of Trinity College, Cambridge, has been nominated to use the university's table at the Zoological Station at Naples.

DR. GREGORY SHWARTZMAN has received a grant from the Committee on Scientific Research of the American Medical Association for work on the "Rous

Agent" to be done in the Mount Sinai Hospital laboratories.

DR. EDWIN O. JORDAN, chairman of the department of hygiene and bacteriology of the University of Chicago, is spending the winter quarter in Jamaica, where he is conducting a special investigation under the auspices of the International Health Board of the Rockefeller Foundation.

PROFESSOR ROBERT REDFIELD, of the department of anthropology of the University of Chicago, in order to continue his field researches in Maya ethnology, is spending six months in southern Mexico.

EARL HANSON, of the department of terrestrial magnetism of the Carnegie Institution of Washington, has returned to the United States after spending eighteen months in the northern part of South America making surveys of terrestrial magnetism.

ABBÉ GEORGES LEMAITRE, professor of mathematics and of the history of the physical and mathematical sciences at the University of Louvain, has left Pasadena, where he has been conferring with Dr. R. A. Millikan, Dr. Albert Einstein and others, to return to Louvain. He will visit Washington and England on the way.

DR. F. BERNSTEIN, director of the institute of mathematical statistics of the University of Göttingen, is visiting the United States, more especially to study the work of Dr. William H. Park and Dr. Keresturi at the Willard Park Hospital on the B. C. G. method of combatting tuberculosis and of Miss Maude Slye, at the Sprague Memorial Institute of the University of Chicago, on the inheritance of cancer in mice.

LLEWELLYN N. EDWARDS, senior highway bridge engineer on the U. S. Bureau of Public Roads, sailed on January 20 for England where he plans to spend three months on research work. On February 15 he will read a paper on "The Evolution of American Bridges" before the Newcomen Society in London.

DR. L. B. TUCKERMAN, retiring president of the Philosophical Society of Washington, on January 14 delivered an address before the society entitled "From Material to Structure."

PROFESSOR WALTER S. RODMAN, of the department of engineering of the University of Virginia, spoke on January 12 on "Thomas Jefferson as a Scientist" before a combined meeting of the Virginia chapters of Sigma Xi and Phi Beta Kappa.

DEAN FRANK C. WHITMORE, of the School of Chemistry and Physics of the Pennsylvania State College, spoke before the Maryland Section of the American Chemical Society in Baltimore on January 20 on "Recent Work on Molecular Rearrangements."

DR. EUGENE C. BINGHAM, professor of chemistry at Lafayette College, will address the sections of the American Chemical Society in the Middle West on "Recent Progress in Rheology" at Indianapolis, Indiana, on February 1; at Dayton, Ohio, on February 2, and at Columbus, Ohio, on February 3.

M. W. STIRLING, chief of the Bureau of American Ethnology, gave a lecture on January 4 at Cornell University entitled "By Airplane to Pigmy Land."

DR. HARRISON S. MARTLAND, chief medical examiner for Essex County, New Jersey, will deliver the ninth Ludvig Hektoen Lecture of the Frank Billings Foundation on February 24. His subject will be "Recent Progress in the Medicolegal Field in the United States."

DR. MARIUS BARBEAU, ethnologist at the National Museum of Canada, delivered an address illustrated with motion pictures and lantern slides on "French Canada: Its Survival" before the Washington Academy of Sciences on January 12.

SIR T. CRISP ENGLISH will give the Hunterian Oration of the Hunterian Society, London, on February 27.

FRIENDS of Sir James G. Frazer have founded a lectureship in the University of Glasgow, a condition of the foundation being that Sir James Frazer, during his lifetime, should deliver in Glasgow one lecture each year. It has been arranged that Sir James Frazer will deliver his first lecture on March 3, 1933.

THE Royal Society Mond Laboratory at Cambridge will be opened by the chancellor of the university, the Right Honorable Stanley Baldwin, on February 3.

WESTERN RESERVE UNIVERSITY has received a gift of three hundred thousand dollars to found the Oliver H. Payne chair of surgery in the School of Medicine. Dr. Carl H. Lenhart has been appointed the first incumbent.

THE late Dr. William Sydney Thayer, of the Johns Hopkins University, left his collection of medical books to the Welch Library of the university and valuable prints to Harvard University.

BY the will of the late William J. Holland his collection of insects is left to the Carnegie Museum, on condition that a fund of $10,000 for making additions to it is set up. Should the Carnegie Museum not accept the bequest the collection goes to the U. S. National Museum.

DR. JAMES ALEXANDER URE, who died on November 20, bequeathed his estate to the University of Glasgow. The bequest, of the approximate value of £13,000, is to be used for scholarships and prizes in medicine, and especially for research on cancer and tuberculosis.

WE learn from the London *Times* that the British Association held on January 6 at Birkbeck College the usual meetings of organizing sectional committees to lay down the lines of the program of the Leicester meeting next September. As under a new statute the annual office of president of the association corresponds with the calendar year, occasion was taken to welcome Sir Frederick Gowland Hopkins, president of the Royal Society, to the chair. Sir Alfred Ewing, the retiring president, in introducing Sir Frederick Hopkins, said that there was no need for him to say how fortunate the association was in securing Sir Frederick Hopkins as president, a man already so preeminent as to be president of the Royal Society. Last year it had been, so to speak, the turn of that part of science which dealt with the constitution of non-living matter and with purely mechanical processes, which could certainly kill, but could not make alive. Now they turned, perhaps with relief and greater hope, to the still more difficult science of life, of whose fascinating problems no one could speak with more authority and clearer discernment than Sir Frederick Hopkins. One felt certain that in his hands the association would lose nothing of the public attention and interest its great annual conference continued to command. More than ever, he believed, the public wished to know about the advances of science, partly because these were now confessedly tentative and incomplete and partly because they might provide some guidance in the urgent perplexities of social affairs. Science had brought new powers and with them new dangers, grave dangers of which the community were scarcely yet aware. It was clearly the duty of science to point these out. After his installation Sir Frederick Hopkins said it was indeed no light task to continue the high tradition attaching to the presidency of the association and he would be well content if he could even approach the standard which Sir Alfred Ewing had so fully maintained.

AT a recent meeting of the directors of the American Chemical Society, the secretary was requested to express the very sincere appreciation of the society to the chemical industry for the aid it has given to *Chemical Abstracts,* and to send those whose agreements expire in 1932 the society's very sincere thanks. The secretary was further instructed to explain to the industry that while there is no hope of *Chemical Abstracts* being continued for any length of time with real efficiency without the continued help of the industry, the society feels that it must draw on its own reserves in 1933 rather than call for further help from the industry under present conditions. The proposal of the editor of *Industrial and Engineering Chemistry* to issue the "Analytical Edition" six times a year instead of four times, as at present, was approved by the directors. His proposal to issue the "News Edition" once a month, on the fifteenth, instead of twice a month, as at present, was not approved, and an additional amount was added to the budget to continue the "News Edition" as at present. It was also voted to defer the issuance of a new directory of the society.

PLANS for an arboretum comparable with the best in the United States are described in the report of the Arthur H. Scott Horticultural Foundation, prepared by John C. Wister, director, and issued as a supplement to the annual report of Swarthmore College. The purpose of the foundation is expressed as a desire "to help horticulture by visual demonstration which can be best realized by the planting in a public place of such trees, shrubs and flowers as can be used by people of average means living in the Philadelphia district." On the campus of Swarthmore the emphasis is placed on showy flowers that are suitable for planting in small gardens. There are at present about fifty kinds of lilacs, nearly fifty kinds of rhododendrons, fifty kinds of azaleas, over thirty kinds of cherries, about thirty kinds of apples, and over 100 kinds each of iris, peonies, daffodils and chrysanthemums—in all about 1,200 different plants. The largest project to be undertaken is the formation of the Scott Arboretum in the Crum Creek Valley, some one hundred and seventy-five acres of virgin timber and uncultivated river silt, which will be divided into four sections. One will contain only those plants, shrubs and trees native to Delaware County; a second area will have trees native to Pennsylvania but not native to Delaware County; a third will have plants and trees native to the North American Continent, and the final group trees which grow in this climate in other parts of the world.

THE next annual congress of the Royal Institute of Public Health will be held at Eastbourne from May 30 to June 4, under the presidency of Viscount Leverhulme. The scientific work of the congress will be conducted in the following sections: (1) State medicine and industrial hygiene; (2) women and children and the public health; (3) tuberculosis; (4) pathology, bacteriology, biochemistry and veterinary medicine; (5) climatology and hydrology. Delegates are being invited from the governments, the municipalities, the universities and other public bodies of Great Britain and Ireland and the British Dominions, as well as from Continental and foreign countries. Arrangements have been made with the railway companies for a reduction in the fares. The headquarters of the institute are now at 23, Queen Square, W.C.1.

Nature reports that the preparatory work of the organizing committee at Stockholm of the next World

Power Conference, which will take place in 1933 in Scandinavia, is proceeding steadily. The first plenary World Power Conference was held in London in 1924, the next in Berlin in 1930. There have also been sectional meetings with special programs, for example, at Basel in 1926 and London in 1928. The Scandinavian Conference will be such a special meeting, dealing with the energy problems of large industry and transport. Participation and collaboration of fifteen countries outside Scandinavia is assured and more than one hundred and seventy reports are announced. Some forty reports to be published at the meeting deal with problems of energy supply in large-scale industry, such as combined power and heat supply, the rôle of large-scale industry in national power schemes, etc. Many of the technical papers deal with the problems of long distance gas transmission, while other papers are devoted to more special power problems concerning the iron and steel industry, pulp and paper, and cement, sugar, textile and other steam heat consuming industries. Energy questions of transport provide the subjects for sixty-two reports; railway and marine transport, the peculiarities of city and suburban traffic are to be discussed with due emphasis on the new aspects which have been introduced by electric traction and Diesel engines.

DISCUSSION

ETHER STRUCTURE

IN SCIENCE for February 21, 1930, I proposed an explanation of the action of electric force and induction across a vacuum, that is, across the ether. The suggestion was to extend to the ether the conception used by Debye, that the dielectric properties of gases and electrolytes depend upon polarized ions or "dipoles" of the medium. The ether is thus to be conceived as having a structure, that is, with "ether dipoles" or polarized cells. From this we get directly the idea that an electric field produces linear arrangements of the ether dipoles, and this may have an effect on polarized light similar to crystal action. I have made an experiment to detect such possible effect. The electric field was between two aluminum strips 60 centimeters long and 1 centimeter wide and 0.5 centimeter apart. This condenser was in a high vacuum. The vacuum was so high that no discharge took place when the condenser plates were charged by a Holtz machine to approximately 30,000 volts. The electric field was horizontal. A beam of polarized light, with polarization plane at 45° to the horizontal was passed across the electric field. Not the slightest effect on the light could be detected when the field was put on and off. The analyzer was of the strained glass bar type ("Rayleigh Compensator") used by the late Lord Rayleigh in his experiment to detect a possible double refraction due to ether drift.[1] The sensitiveness was at least six seconds of rotation per centimeter beam length in the field. The field was about 60,000 volts per centimeter. Thus this experiment to detect an ether structure, like experiments for ether drift, gave a negative result. On a corpuscular light theory, the above experiment can also be interpreted as showing no electric moment of the light corpuscle or photon in the above conditions.

ALBERT P. CARMAN

UNIVERSITY OF ILLINOIS

[1] *Phil. Mag.*, p. 680, 1902.

ENERGY OF UREA SYNTHESIS

IN the study of the energy change in the synthesis of urea from ammonia and carbon dioxide by liver slices we have found that synthesis of urea is accompanied by a definite and measurable increase in oxygen consumption. Our present facilities do not permit of precise measurements, but the results so far obtained suggest that one additional molecule of oxygen is used for every molecule of urea synthesized. Similar values were obtained with both glucose and d-1 lactate as fuel, and with and without ornithine. Comparison of the rates of synthesis of urea suggest that the fuel in this reaction is lactate or some product derived from it. It seems unlikely that more than a fraction of the specific dynamic action of protein can be accounted for by the superfluous energy released in the synthesis of urea from ammonia. Further experiments are in progress.

H. BORSOOK
G. KEIGHLEY

W. G. KERCKHOFF LABORATORIES OF THE BIOLOGICAL SCIENCES,
CALIFORNIA INSTITUTE OF TECHNOLOGY

HETEROSIS: SPECIFIC NOT GENERAL IN NATURE

IN studies of hybrid vigor or heterosis in F_1 oat plants, variable results were obtained from different crosses. In the F_1 of some crosses nearly all the measurable parts are greater in the F_1 hybrid than in the larger parent. In other crosses possibly only one or two characters are noticeably increased. The difficulty of obtaining oat crosses in large numbers is a serious obstacle to studies of heterosis in oats, but it is believed that an increase of 10 per cent. over the larger parent may safely be considered a significant increase where small numbers are involved. Examples of these results are found in the cross Richland × Fulghum and Richland × Markton. In the first cross the F_1 plants averaged 13.2 per cent. taller, bore

17.5 per cent. more culms per plant, weighed 48.5 per cent. more, and yielded 35.2 per cent. more grain and 51.3 per cent. more straw on the average than the larger parent. In all other characters the hybrids were intermediate between the parents. In the second cross the F_1 plants yielded 18.9 per cent. more grain, and the grain-straw ratio was increased 33.8 per cent. over that of the larger parent. In all other characters the F_1 plants of this cross were intermediate in size between the parents. In other crosses other characters manifested the influence of heterosis.

Heterosis is commonly accepted as having a genetic basis and as such this increase in plant size is satisfactorily explained as being due to the bringing together in the F_1 of the growth factors present in both parents. The impression seems quite generally held that when heterosis occurs in an F_1 hybrid individual the increased size is of a more or less general nature, extending to all or most all the measurable parts of the hybrid organism. In the light of available knowledge it appears that this widely held conception may need some revision. Barring actual linkage, heterosis is a condition which more often has a rather high degree of specificity. In some crosses a number of the parts of the F_1 hybrid plant may show influence of heterosis, yet it does not necessarily follow that the parts are closely linked genetically. The fact that in some F_1 crosses only a single plant part shows the influence of heterosis, while in others there may be several showing increased size, definitely indicates lack of genetic linkage.

F. A. COFFMAN

BUREAU OF PLANT INDUSTRY
U. S. DEPARTMENT OF AGRICULTURE

THE PRODUCTION OF NUTRITIONAL ANEMIA IN WHITE RATS

I HAVE read with interest the artitcle entitled, "A Reliable Method for the Production of Nutritional Anemia in White Rats," by Robert S. Harris, which appears in SCIENCE for November 25. We have been feeding Klim to produce anemia in this laboratory for some time. At first[1] we reconstituted it by adding water, but for nearly two years now we have been feeding the dry powder, and have suggested it to a number of other laboratories.

Klim, being dried by a spray process, has less opportunity for metallic contamination than drum process milk powders. By purchasing in quantities of 500 pounds or more we have been able to standardize on the product of one plant, which runs quite uniform at 3 to 5 parts per million of iron and 1 to 2 parts per million of copper. This amount of copper corresponds very closely with that shown to be present in uncontaminated whole milk from different areas by Elvehjem and Steenbock and Hart.[2]

That Harris is able to produce a more pronounced anemia in a shorter time than we have reported[3] is probably due to a difference in method of handling prior to placing on the Klim diet. Elvehjem and Kemmerer[4] have shown that if young rats from the twelfth day, when their eyes open, do not have access to any supplemental food other than cow's milk, anemia develops very rapidly, whereas if allowed to partake of the usual solid breeding diet between the 12th and 21st (or 28th) day of age, development of anemia on a subsequent milk diet is much slower.

Harris' observation that there is an inverse relationship between rate of growth and hemoglobin is in agreement with the findings of other laboratories.

ROE E. REMINGTON

MEDICAL COLLEGE OF THE
STATE OF SOUTH CAROLINA

MOSQUITOES KILL LIVE STOCK

REPORTS of the death of live stock and even of man as a result of mosquito attack are current, but apparently few of these have been verified. It seems desirable, therefore, to record a recent outbreak of *Psorophora columbiae* Dyar and Knab, in Florida, which resulted in the death of at least 173 head of live stock and poultry.

This outbreak came suddenly and with great fury on the night of September 5 and continued for several days. The losses were most severe the first night, many animals being found dead or nearly so the following morning. Mr. T. E. McNeel, of the Bureau of Entomology, who investigated the outbreak several days after it occurred, made a careful check on reported losses in the vicinity of Miami and verified reports of the death loss of 80 cattle, 67 hogs, 3 horses, 1 mule, 20 chickens and 2 dogs. Reports of losses at other points in the vicinity of the Everglades have been recorded, but have not been checked. Mr. C. D. Mathews, chief of the Bureau of Dairy Inspection of Miami, stated that the milk supply from the Hialeah district was reduced by about 1,000 gallons a day from September 6 to 10 and had not returned to normal on September 20.

The death of the animals was attributed by many to blood loss. The manager of the Miami Soap Company, who received most of the dead stock, stated to Mr. McNeel that when the heads of the animals were cut off there was no flow of blood as normally occurs.

[1] Levine, Remington and Culp, *Jour. of Nutrition*, 4: 469, 1931.

[2] *J. Biol. Chem.*, 83: 27, 1929.

[3] Levine, Culp and Anderson, *Jour. of Nutrition*, 5: 295, 1932; and Coulson, Levine and Remington, *Amer. Jour. Public Health*, 22: 1141, 1932.

[4] *Jour. Biol. Chem.*, 93: 189, 1931.

Dr. H. E. Miller performed post-mortem examinations on a number of the animals and stated that no mosquitoes were found in the air passages. While blood loss was no doubt an important factor, it is the writer's opinion that the death of the stock may have been due to the injection of a toxin by the mosquitoes as well as to the loss of blood.

In the case of the larger herds the cattle apparently protected themselves to some extent by bunching closely together, and those which had access to the canal stayed in the water up to their heads, and very little loss occurred in these herds. Smudges and applications of grease and oil were extensively used, and no doubt prevented greater death losses.

Psorophora columbiae is one of the smaller species of the genus. The eggs are laid on the soil and hatch quickly when submerged. Thus, great swarms of adults emerge almost simultaneously when egg-bearing areas are flooded. The species is usually of little importance as a pest of man. In this outbreak, however, it is reported that men who were making smudges and otherwise looking after stock had to wear heavy coats and blankets to protect themselves, and some of them stated that they were sick for several days from the bites of the mosquitoes.

F. C. BISHOPP

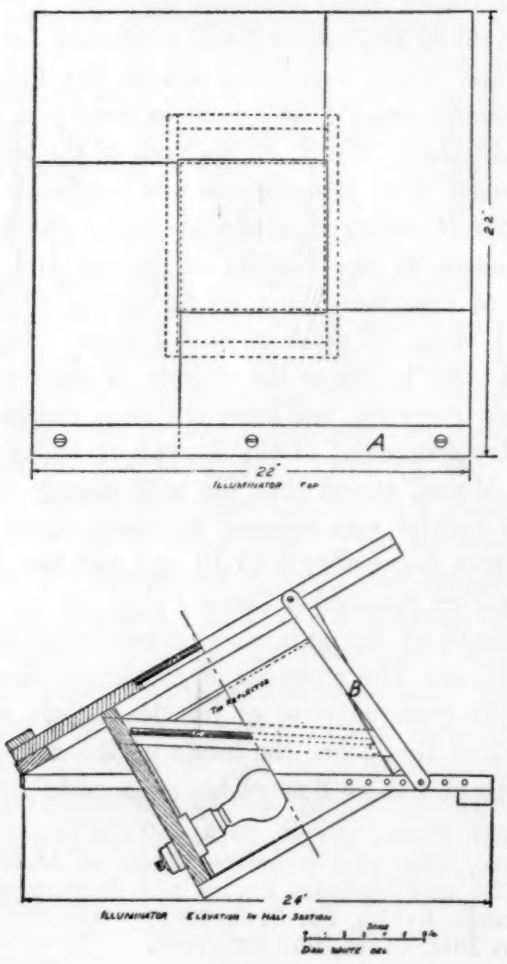
BUREAU OF ENTOMOLOGY
U. S. DEPARTMENT OF AGRICULTURE

SCIENTIFIC APPARATUS AND LABORATORY METHODS

AN ILLUMINATOR TO FACILITATE THE TRACING OF X-RAYS

IN studying x-rays of the organs of speech it is frequently necessary to make tracings of the films. Manufactured illuminators, intended for viewing films, are inadequate for tracing. They provide no surrounding board to which materials may be fastened; they are not convenient to work on; they heat up rapidly; and they are expensive.

The illuminator shown in the figure can be made cheaply and has none of these disadvantages. It consists primarily of an ordinary drawing board which can be tilted to any convenient angle by shifting the support (B). The strip (A) prevents objects from sliding off. A removable glass (D) of the appropriate size is set in the center of the board. Clear or opalescent glass may be substituted at will. (C) is a piece of clear glass between the bulb and the surface glass to deflect and absorb the heat. It, also, is removable to permit easy changing of the lamp. The tin reflector spreads at the sides to allow free ventilation. This illuminator has been used for several hours at a time without gettting hot.



Masks of black paper, to cover all but the parts being traced, are provided and may be pinned to the board. By their use lines in the x-ray which seem to have been obliterated by overexposure can frequently be found and traced.

C. A. BEVANS

PHONETICS LABORATORY
THE UNIVERSITY OF CHICAGO

A LARGE RESPIROMETER[1]

IN making some studies of the catalase, nitrogen and carbohydrate changes in asparagus roots after various treatments to break dormancy it was thought desirable to have some information on the respiration while these changes are going on.

Many difficulties were experienced in finding a respirometer which could be satisfactory. Nothing found in the literature described containers large enough to hold the plant roots which were being studied. The usual NaOH containers were too small to hold the amount of carbon dioxide given off in a 48 hour period, and more frequent weighing and measuring was not thought worth while.

After many different set-ups were made and several

[1] Contribution No. 113, Department of Horticulture, Kansas Agricultural Experiment Station.

different arrangements were tried, one which is herewith described (Fig. 1) was found satisfactory in

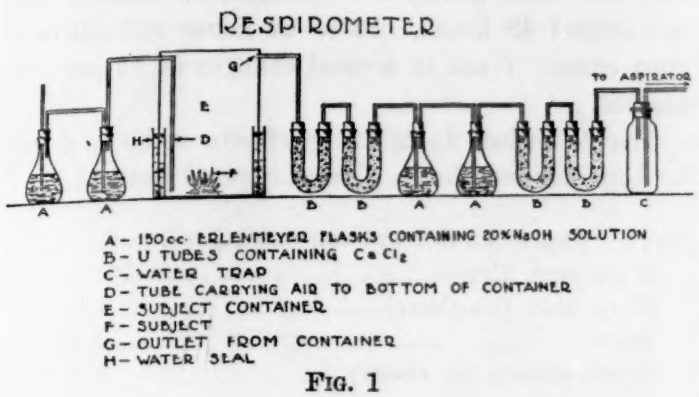


FIG. 1

every respect, including low cost for material and equipment.

The principal divergence from the customary respirometer is the subject container. This was made of galvanized iron. The air which has had the carbon dioxide removed in the pair of NaOH bottles (A) is drawn in at the top of the respiration chamber and carried to the bottom of the container in the metal tube (D). The air with the carbon dioxide of the asparagus respiration is then carried out of the container from the top through the opening (G). In this way there is a continuous change of the air in the container.

In using this container the greatest difficulty was experienced in making an air-tight seal which could be broken easily and frequently for examination of the asparagus root. Sealing wax, paraffin, grafting wax and similar materials had many objections. In no case could a tight seal be held for more than 12 hours, because the waxes withdrew from the galvanized iron container and the base, whether the base was metal or glass. To avoid this difficulty a base was made for the container, and in this base is a double-walled collar. The asparagus roots were set in this base. The side of the galvanized iron subject container fitted in between the walls. The double wall was then filled with water. No further trouble was experienced with air leaking through the container, and the respirometer has been in continuous operation for as long as 48 hours and no leaking has been detected.

An easy check for leaks is made by setting the respirometer up without putting a plant in the container. By introducing carbon-dioxide free air into the container and then passing the air through the entire apparatus the operator is able to take some carbon dioxide out at the aspirator, if there is any leaking in the system. None has been found after two interrupted 24-hour tests and one continuous 48-hour test.

This apparatus has the advantages of being easily and cheaply constructed, can be opened and closed easily and seemingly is satisfactory for measuring the amount of carbon dioxide given off by plants in the dark.

WALTER B. BALCH

NEW FIXING FLUIDS FOR GENERAL PURPOSES

THE number of fixing fluids recommended up to date is admittedly very great. The excuse for the new formulae given here lies in the fact that all other fluids with which I am familiar, either harden the tissues too much or interfere with subsequent staining. Serial sectioning is often made very difficult, while macroscopic dissection becomes almost impossible. In addition, many fluids require prolonged washing. The duration of fixation is also often very limited, resulting in great inconvenience when one attempts to use the fluids on scientific expeditions. The new fluids recommended here represent the results of extensive experimentation extending over many years and are more or less free from the above-mentioned defects. Animals fixed in them remain soft and do not harden subsequently in 70 per cent. alcohol in which they may be left for many weeks. Washing is simple. All common stains may be used. Mallory's triple stain gives brilliant differentiation, though the picture is somewhat different from that obtained after fixation in Zenker's fluid. Complete penetration of all ingredients of the fluids is accomplished at the rate of one half millimeter per hour, but the nitric acid penetrates twice as rapidly. This was determined by an examination of pieces of liver at intervals of one hour. The surface of a smooth cut shows the fixed zone clearly. The penetration of paranitrophenol was determined by wetting the cut surface with ammonia and measuring the width of the zone in which the tissues turned yellow. Similarly, the penetration of cupric nitrate was determined with sodium sulfide.

The change in volume due to fixation was determined by measuring the displacement of water before fixation and after fixation. This was done by Dr. G. E. Pickford, who found an average swelling of about 10 per cent. in beef liver fixed for 24 hours in the phenol and the paranithrophenol mixtures, while in the case of the alpha dinitrophenol mixture the increase in volume was only about 5 per cent. A paranitrophenol mixture made up with 70 per cent. instead of 60 per cent. alcohol caused a swelling of about 20 per cent. Rat testes showed a shrinkage of about 5 per cent. after 24 hours fixation in the phenol mixture, but no appreciable change of volume after fixation in the paranithrophenol mixture. When transferred to 70 per cent. alcohol for 9 days, both showed an increase in volume; in the case of the testis fixed in the phenol mixture the increase amounted to about 13.5 per cent., in the case of that fixed in the paranitrophenol mixture to about 16 per cent. Transferred for 10 days into 80 per cent.

alcohol the first testis showed no further change in volume, while the second showed an increase to about 20 per cent. of its original size.

Phenol gives a peculiar elastic texture to the tissues, unlike anything produced by commonly used fixing fluids. Paranitrophenol comes nearest to phenol in this respect and, being stable in the mixture, is preferable where stability is desired. I have used both mixtures for arachnids, insects, myriapods, leeches, earthworms, flatworms, roundworms, older amphibian larvae and mammalian embryos. Professor J. S. Nicholas, of our department, is using my paranitrophenol mixture for rat embryos and fish in preference to sublimate or Bouin, while Professor W. R. Coe finds it very satisfactory for nemerteans. Macroscopic dissection of invertebrates and mammalian embryos fixed in either of these fluids is greatly facilitated.

No. 1. *Cupric-phenol fixing fluid.*

Stock Solution A.

Distilled water	100 cc
Nitric acid, c.p., sp.gr. 1.41–1.42	12 cc
Cupric nitrate, c.p., crystals $Cu(NO_3)_2 \cdot 3H_2O$	8 grams

Stock Solution B.

80 per cent. alcohol	100 cc
Phenol, crystals, c.p.	4 grams
Ether	6 cc

The stock solutions are perfectly stable and may be kept in glass-stoppered bottles. For use take: Solution A—1 part, Solution B—3 parts. The mixture does not keep and must be used within a few hours. For the same reason the duration of fixation must not exceed 48 hours. 12 to 24 hours will suffice in most cases. Wash in several changes of 70 per cent. alcohol.

The following fluids are perfectly stable and may be kept for months in glass-stoppered bottles:

No. 2. *Cupric-paranitrophenol fixing fluid.*

60 per cent. alcohol	100 cc
Nitric acid (as above)	3 cc
Ether	5 cc
Cupric nitrate (as above)	2 grams
Paranitrophenol, c.p., crystals	5 grams

Duration of fixation not limited by time, except as to the minimum time required for penetration at the rate of one half millimeter per hour. Wash in several changes of 70 per cent. alcohol.

No. 3 to No. 6: These fixing fluids have the same composition as No. 2, except that in place of 5 grams of paranithrophenol they contain 0.5 gram of one of the following nitroderivatives of phenol: No. 3—orthonitrophenol, No. 4—alpha (2:4) dinitrophenol, No. 5—beta (2:6) dinitrophenol, No. 6—picric acid (2:4:6 trinitrophenol). Fixation and washing as in No. 2, but Nos. 5 and 6 require longer washing and leave the tissues yellow.

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SPECIAL ARTICLES

VARIATIONS IN VISIBLE SOLAR LIGHT DURING SUBMARINE MEASUREMENTS

WHILE making measurements on the intensity of some of the components of visible solar light beneath the surface of ocean waters, variations in the intensity of the incident light were found to be of such magnitude, on some days, that considerable uncertainties are introduced into the results if these variations are unaccounted for. These variations are not ones which depend upon zenith distance, but are occasioned by other circumstances. They are of particular importance when the depth of water is such that very small currents result in the submerged photoelectric cell. These variations occur on days when the sky is cloudless and the atmosphere very clear to the eye.

The time required to make a series of measurements of illumination intensity beneath the sea with a photoelectric cell to a depth of 50 meters, say, is an hour or more if one-meter intervals are chosen as unit layers of the absorbing medium. During this time the illumination intensity of the radiation incident upon the surface of the water changes slowly with the variation in the solar zenith distance. Also, the intensity of the visible light may vary within a few minutes by several per cent., even though there be a cloudless sky and a clear atmosphere. A study of these variations made during the summer of 1932 at the Friday Harbor (Washington) station of the Oceanographic Laboratories also show that a record of the total radiation intensity on a horizontal surface is not indicative of all changes which may occur in the illumination intensity.

Such variations are shown in Fig. 1. The total radiation was measured by means of an Eppley pyrheliometer connected to an Engelhard recorder. This instrument had recently been calibrated by Dr. Herbert H. Kimball in charge of solar radiation for the U. S. Department of Agriculture. The illumination intensity was measured by means of a calibrated photoelectric cell.

The curves in Fig. 1 are characteristic of the obser-

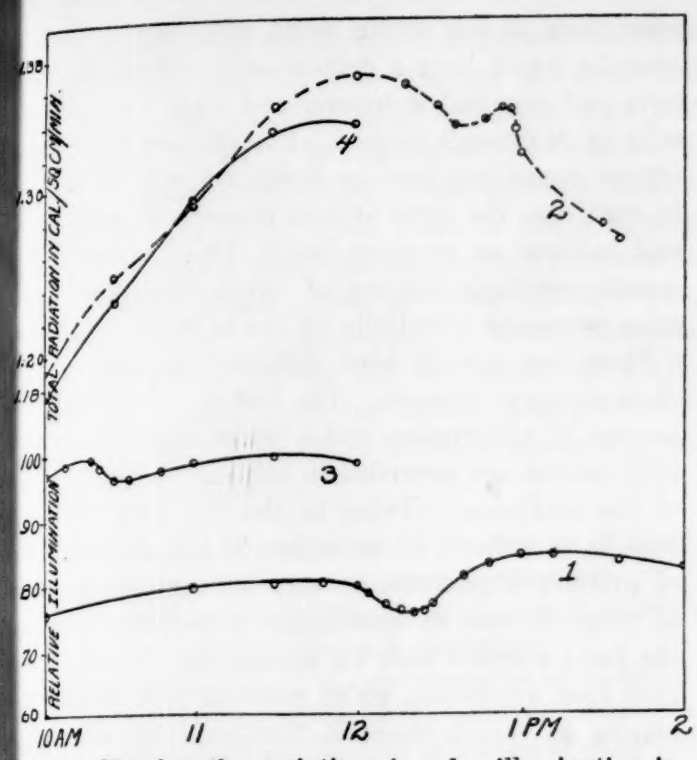

FIG. 1. Showing the variations in solar illumination intensity and total radiation.

vations. In making the observations the pyrheliometer and the cell were located near each other. Days were selected when there was no evidence of clouds or haze. The air in the region of the laboratories was entirely free from smoke. The days on which observations were made can well be called clear and cloudless.

Curves 1 and 2 were plotted from observations made on July 26, while curves 3 and 4 show the variations several days later. Curves 1 and 3 show the variations in the solar illumination intensity. Curves 2 and 4 show, respectively, the simultaneous variations in the total radiation. These data were selected from a series of observations to exhibit the magnitude and rapidity of the changes in illumination.

It is at once apparent from the illumination curves that on these days rather rapid changes are superimposed upon the changes due to zenith distance. Also, changes in illumination are not indicated by changes in the total radiation, although in curve 2 of July 26 a rather small but sudden change occurs in the total radiation at 11 A. M., and another more marked change between 12:40 and 1 P. M. Curve 4 shows only the gradual change in total energy, while simultaneous readings of illumination show a sudden change at about 10:20 A. M.

That a relation exists between radiation intensity and illumination has been shown by Kimball.[1] This relation is that radiation in calories per minute per cm^2 on a horizontal surface multiplied by 6,700 will give the illumination in foot-candles on a horizontal surface within ± 5 per cent., the variation being characteristic of the position of the sun. This relation agrees, in general, with the present results, but does not account for the rapid changes found.

In a study of the penetration of light into water, Shelford and Gail[2] did not take into account any variations in the incident light, although they apparently suspected variations to exist. In a later study, Shelford[3] *assumes* that, under a cloudless sky and a very clear atmosphere, the intensity of the visible solar light incident on the surface of water is constant between the hours of 10 A. M. and 2:30 P. M. Variations due to solar zenith distance and the smaller variations illustrated in curves 1 and 3 show that such constancy does not exist.

Poole and Atkins,[4] during a series of determinations of the penetration of the *total* visible light into the sea near Plymouth, found variations in the incident light with a bright sun, although they do not state that the sky was cloudless and the atmosphere clear.

It is evident that in making measurements of the absorption of visible light by ocean waters a knowledge of the variations in the incident light is quite necessary. The results of a study of the penetration of some of the components of visible solar light into the waters of Puget Sound and of Southern Alaska will be published soon.

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[1] H. H. Kimball, *Mo. Weather Rev.*, 52: 473, 1924.

BORRELIOTOSES: FOWL-POX, MOLLUSCUM CONTAGIOSUM, VARIOLA-VACCINIA

THE judgment first expressed by Borrel,[1] that the specific granules of fowl-pox may well be the actual virus of this disease, a view later held by Lipschütz and by Paschen with respect to the specific granules of molluscum contagiosum and vaccinia, has received from recent studies strong support. Evidence has likewise accumulated which effectively upholds the view that the specific cellular inclusions (Bollinger bodies, molluscum bodies, Guarnieri bodies) of these three infections are composed essentially of colonies of the respective viruses which appear to be microorganisms and seem to require an intracellular environment in their hosts for their reproduction.[2, 3, 4, 5]

[2] V. E. Shelford and F. W. Gail, *Pub. Puget Sound Biol. Sta.*, 3: 141, 1922.

[3] V. E. Shelford, *Pub. Puget Sound Biol. Sta.*, 7: 151, 1929.

[4] H. H. Poole and W. R. G. Atkins, *Jour. Marine Biol. Assoc.*, 14: 170, 1926; *ibid.*, 15: 455, 1928.

[1] A. Borrel, "Sur les inclusions de l'epithelioma contagieux des oiseaux," *Compt. Rend. Soc. Biol.* 57: 642, 1904.

[2] C. E. Woodruff and E. W. Goodpasture, "The Infectivity of Isolated Inclusion Bodies of Fowl-Pox," *Amer. Jour. Path.*, 5: 1, 1929.

[3] E. W. Goodpasture and C. E. Woodruff, "A Com-

This evidence in substance may be summarized as follows: It has been demonstrated that the specific cellular inclusions of fowl-pox, molluscum contagiosum and vaccinia, namely, the Bollinger bodies, molluscum bodies and the Guarnieri bodies, are composed in large part of compact aggregations of enormous numbers of specific granules, respectively the Borrel, the Lipschütz and the Paschen corpuscles. There is good evidence that the great mass of these corpuscles if not all are regenerated within the infected cell. In the case of fowl-pox it has been proven that individual inclusions are totally and fractionally infective.[6] The corpuscles of fowl-pox, molluscum and vaccinia are demonstrably filterable. These granules, unlike the banal proteid granulations of cells, are not dissolved by dilute acids and they are resistant to tryptic digestion. They are likewise insoluble in lipoid solvents. In the case of the granules of fowl-pox and vaccinia there is agglutination in the presence of specific immune serum,[7] and in suspensions of virus centrifuged at high speed there is a marked parallelism between the concentration of specific granules and the concentration of virus. The vaccinia corpuscles have been found to increase in tissue cultures containing the virus. There is morphologic evidence of division of the granules by fission. Finally these granules react characteristically to certain staining methods, notably the silver method of Morosow, so that demonstration of them in preparations which contain them in considerable amount is thoroughly reliable in the hands of competent observers.[8] They are not readily or at all exhibited by the staining methods used to demonstrate bacteria. While the final demonstration of reproduction of these granules in the absence of tissue cells has not yet been attained, there is sufficient reason for judging that one is dealing here with a group of viruses which are micro-organisms and, in natural infections, obligatory cytotropes.

In the entire field of cytotropic viruses these are the only ones which present conclusive evidence of an association of the active agent with minute coccoid granules which have a definite and uniform morphologic and physical structure, and stain characteristically by Morosow's method. The diseases which these viruses cause are also in many respects analogous. In each case the virus attacks ectodermal epithelium, and induces an eruptive lesion which presents the specific cytologic feature of intracytoplasmic inclusions composed essentially of the uniform corpuscles.

There has always been difficulty in unifying the virus group of diseases. The fact of filterability, the concept of cytotropism and a better understanding of viral lesions are nevertheless helping to resolve some of the confusion. Owing to the fact that the virus class is so difficult of definition, it has seemed to me of primary importance to correlate any small group of virus diseases as specifically as possible whenever the facts warrant such an association. The group I have been discussing, which contains such notable examples as variola-vaccinia, fowl-pox and molluscum contagiosum, is at the present time separable from the general class of virus diseases into a more homogeneous one because of the presence of visible granules which have definite and similar characteristics and constitute an essential part of their analogous specific lesions. I therefore think it justifiable at this time to designate this group by generic and specific names on the basis of their specific granules, and I would suggest that fowl-pox be taken as the generic type. It was Borrel who in 1904 first discovered the specific coccoid granules of this disease, and later investigators have shown that they constitute the essential component of the cellular inclusions, that they are fractionally infective, and that the so-called Borrel bodies are filterable and specifically agglutinable by immune serum. It would therefore seem appropriate that Borrel's name should be associated with this group.

There is no adequate proof, however, that the granules of these diseases are viable, nor for that matter, that any cytotropic virus is a living thing; consequently a name which would at present classify these corpuscles among the living agents of disease might be misleading. One should rather choose a specific name which is non-committal as to the biological status of the agent.

I would therefore propose the name *Borreliota* as a generic title. The suffix *iota,* the Latinized name of the smallest Greek letter, has I am told by reliable authorities, an ancient and honorable usage signifying smallest particle. Translated in this sense the title Borreliota would mean the small particles or corpuscles of Borrel. The form Borreliota is either singular or plural.

The difficulty of applying specific terminology to

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parison of the Inclusion Bodies of Fowl-Pox and Molluscum contagiosum," *Amer. Jour. Path.,* 7: 1, 1931.

[4] E. G. Nauck and E. Paschen, "Der Morphologische Nachweis des Pockenerregers in der Gewebekultur," *Zentralbl. f. Bact.,* 124, (Orig): 91, 1932.

[5] E. W. Goodpasture, A. M. Woodruff and G. J. Buddingh, "Vaccinal Infection of the Chorio-allantoic Membrane of the Chick Embryo," *Amer. Jour. Path.,* 8: 271, 1932.

[6] C. E. Woodruff and E. W. Goodpasture, "The Relation of the Virus of Fowl-Pox to the Specific Cellular Inclusions of the Disease," *Amer. Jour. Path.,* 4: 713, 1930.

[7] J. C. G. Ledingham, "The Aetiological Importance of the Elementary Bodies in Vaccinia and Fowl-Pox," *Lancet,* 525, Sept. 5, 1931.

[8] M. A. Morosow, "Die Färbung der Paschenschen Körperchen durch Versilberung," *Centralbl. f. Bakt.,* I. Orig., 100: 385, 1926.

certain members of this group is apparent when one considers the fact that the virus of smallpox and that of cow-pox, while differing in certain important ways, are in reality to be considered modifications of the same virus, because they cross-immunize against each other. In other words there is not a specific difference between them, and this probably applies to other modified strains such as those of horse-pox, swine-pox, goat- and sheep-pox. It would therefore seem advisable to use not only a specific, but a subspecific or variety name for the corpuscles of such related strains. I would therefore propose the following terminology:

Borreliota variolae hominis: specific corpuscles of smallpox (Paschen bodies, elementary corpuscles).
Borreliota variolae bovis: specific corpuscles of vaccinia (Paschen bodies, elementary corpuscles).
Borreliota variolae equi: specific corpuscles of horse-pox.
Borreliota variolae porci: specific corpuscles of swine-pox.
Borreliota variolae ovium: specific corpuscles of sheep and goat-pox.
Borreliota mollusci: specific corpuscles of molluscum contagiosum (Lipschütz corpuscles).
Borreliota avium: specific corpuscles of fowl-pox (Borrel corpuscles).

The acceptance of such a nomenclature based upon adequate experimental data would do much to attract attention to this related group as a whole, and would obviate the great confusion of terms now in use such as Borrel bodies, Lipschütz granules, Paschen corpuscles, elementary bodies and so on. At the same time the probability that the specific granules in question represent micro-organismal etiological agents would be duly recognized.

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A CONTRIBUTION TO VOWEL THEORY[1]

Two main theories of vowel production have been advanced, namely, the harmonic or steady state theory and the inharmonic or transient theory. The harmonic theory, advocated mainly by Wheatstone, Helmholtz and D. C. Miller, holds that the vocal cords generate a complex wave having a fundamental and a large number of harmonics. A wave at its source will contain all the frequencies that it will ever contain. The so-called resonating cavities (pharynx, mouth, nasal cavities, paranasal sinuses) will act to magnify those frequencies of the wave near the resonating frequencies of the cavities, the amount of amplification depending upon the damping constant of the cavity. The reinforced frequency bands determine the vowel quality.

The inharmonic or cavity tone theory, advocated mainly by Dodart, Willis and Scripture, holds that the wave or series of puffs from the vocal cords acts only as an agent for exciting the transient frequencies that are characteristic of the resonating cavities. Certain frequencies in the wave need not be present in the source but may be added by the resonating chambers. According to this theory, the vocal cords emit puffs of air, each puff setting the air in the above cavities into vibration, resulting in the so-called "cavity tones." The frequency of a cavity tone is determined by the natural frequency of the cavity, and is not dependent on any frequency aspect of the exciting or cord tone. This vibration of the cavity tone soon diminishes until it is started anew by a second puff. Here, as with the harmonic theory, the vowel quality is dependent upon the natural frequencies and damping constants of the vocal cavities.[2] The findings reported in the present paper tend to add weight to the inharmonic or cavity tone theory.

In order to delimit sharply the problem the head and neck of a cadaver was used to furnish the so-called resonating cavities and a pure sine wave as the force to act on these cavities. Our specimens (two male) presented normally extensive sinuses and normal nasal, oral and pharyngeal cavities (determined by sectioning the head after completion of the experiment). The soft palate was so fixed as to present an opening into both the nasal and the oral cavity which were patent. Both specimens had teeth. The source of the sine wave was a General Radio low frequency oscillator Type 377–B, activating a high-grade head phone. The waves were conveyed to the larynx or directly to the microphone from the head phone by a rubber tube 90 cm long and with a lumen 5 mm in diameter. For studying and recording the waves a Jenkins and Adair C6 condenser microphone with one additional stage of high quality amplification and a Westinghouse oscillograph were used. For all frequencies scouted, 120, 200, 300, 400, 500, 600, 700, 800, 900, 1000 and 1200 ~, the waves were studied first by holding the end of the tube carrying the sound directly in front of the microphone. With the exception of one frequency, 120 ~, all frequencies presented sine waves. Secondly, the waves were studied by placing the nose and mouth of the cadaver directly in front of the microphone after the rubber tube had been inserted through the trachea, into the ventricle of the larynx, just above the level of the vocal cords. The head was suspended from the ceil-

[1] This paper reports a part of a larger research program suggested by the late Dr. Henry J. Prentiss, head of the department of anatomy, University of Iowa. The program is now being kindly supported by Dr. E. M. MacEwen, present head of the department of anatomy.

[2] For a fuller discussion of vowel theories see H. Fletcher, "Speech and Hearing," 1929, Macmillan; and G. O. Russell, "The Vowel," 1928, Ohio State University Press.

ing by small wires in order to avoid the possible resonating effects which might come from supporting it on a table or platform.

For specimen No. 1 the sine waves of frequencies of 200 and 300 ~ and for specimen No. 2 the sine waves of frequencies 200, 500 and 900 ~ were altered in their passage through the specimen. Fig. 1 shows the relatively pure sine waves of a frequency of 200 ~ as they were taken directly from the end of the rubber tube. Fig. 2 shows the change produced in this frequency when the tube was inserted into the larynx of specimen No. 2. Fig. 3 shows the change produced in the sine waves of a frequency of 300 ~ by specimen No. 1.

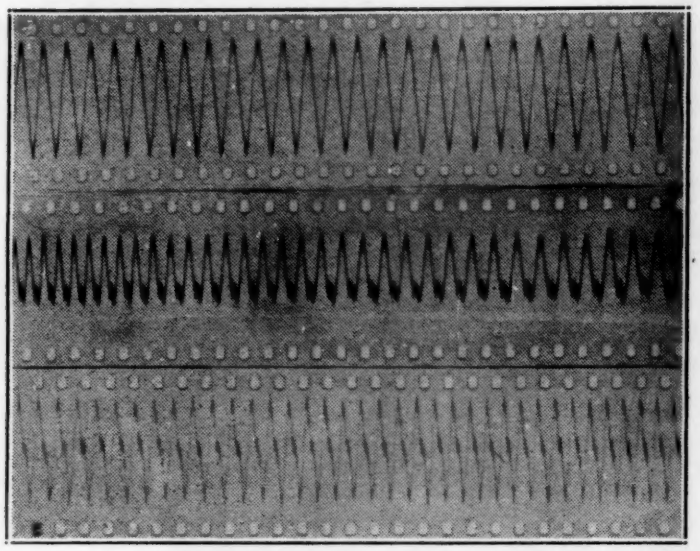

FIG. 1. Oscillogram of relatively pure sine waves (200 ~) led into the larynx of the cadaver. FIG. 2. Oscillogram of the waves emerging from the nose and mouth of the cadaver (specimen No. 2) when the waves depicted in Fig. 1 were being led into the cadaver's larynx. FIG. 3. Oscillogram of the waves emerging from the nose and mouth of the cadaver (specimen No. 1) when relatively pure sine waves of 300 ~ were being led into the cadaver's larynx.

There was a possibility that these changes might be due to the additional column of air imposed upon the vibrating diaphragm of the head phone by the cavities of the head and neck. This was tested by substituting a cardboard cylinder with a small input and output hole for the specimen. The waves emerging from this cylinder proved to be identical with those put into it. The possibility that these changes might be reflected waves was ruled out on the basis of the fact that all relationships between objects in the room were the same for the picking up of both the original input waves and those passing through the specimen. It appears that the alterations in the original waves emerging from the inserted tube occur during the passage of these waves through the cavities of the neck and head of the cadaver. Furthermore, the distortions are not a function of amplitude because the modified wave is smaller than the input wave.

With a more complicated original wave form, one might expect to obtain more striking structural changes in the waves as they emerge from the mouth and nose. We chose purposely the simple sine wave as the one to be modified, reasoning that any change produced in its form would be conclusive in regard to the point in question.

Because the recorded differences between the original waves and those emerging from the cadaver occur between the end of the inserted tube in the larynx and the nasal and oral openings, our results tend to support the cavity tone theory of vowel production. The resultant wave, being no longer pendular, must contain frequencies not present in the source and hence necessarily introduced by the cavities. Certain frequencies were not changed, probably because they did not excite the transient frequencies which were characteristic of the cavities. A close examination of the modified waves shows that a given wave may not be a perfect duplicate of its predecessor; *i.e.*, there is not absolute periodicity in the wave chain. This fits in well with Scripture's general conception of the inharmonic theory that each succeeding puff of air from the vocal cords changes the cavities' contents so that the cavities need not be exactly the same from puff to puff. If our input sine waves contained concealed harmonics, then our results are not so conclusive in favor of the inharmonic theory. However, it is thought that the waves emanating from the cadaver contained frequencies which were not present in the source.

It remains to attack the problem of vowel production with respect to both simple and more complicated input waves in relation to the condition, size and number of the so-called resonating chambers.

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BOOKS RECEIVED

BERLAND, LUCIEN. *Les Arachnides.* Vol. XVI, Encyclopédie Entomologique. Pp. 485. 636 figures. Lechevalier, Paris. 150 fr.

GLENN, OLIVER E. *The Sources of Error.* Pp. 127. Stratford. $1.50.

HILL, A. V. *Chemical Wave Transmission in Nerve.* Pp. ix + 74. 13 figures. Macmillan. $1.25.

MONROE, PAUL, EDITOR. *Report of the Educational Inquiry Commission, Government of Iraq.* Pp. 170. Government Press, Bagdad.

Tôhoku Imperial University. Science Reports. Vol. XXI, No. 4. Pp. 270. Illustrated. Maruzen, Tokyo.

VON ZITTEL, KARL A. *Text-book of Paleontology.* Vol. II: Vertebrates, Fishes to Birds. Revised by Arthur S. Woodward. Pp. 464. 533 figures. Macmillan. $7.50.